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HYDROPOWER

THE REPUBLIC OF UZBEKISTAN
MINISTRY OF HIGHER EDUCATION, SCIENCE AND INNOVATION

TASHKENT STATE TECHNICAL UNIVERSITY
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HYDROPOWER

(INTRODUCTION)

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Mazkur darslik 5311100 – “Gidroenergetika” yo‘nalishi bo‘yicha ta’lim olayotgan bakalavr talabalari uchun mo‘ljallangan bo‘lib, “Gidroenergetika (yo‘nalishga kirish)” fani bo‘yicha o‘quv va ishchi dasturlariga muvofiq tuzildi.

Darslikda barcha mavzular bo‘yicha tayanch so‘z va iboralar hamda nazorat savollari berilgan. Bunda gidroenergetikaning gidravlik asoslari, suv manbalaridan mukammal foydalanish, gidroelektrostansiyalar va nasos stansiyalari xillari, asosiy parametrlari va jihozlari, binolari va inshootlari, bosim quvurlari, gidroakkumulatsion elektr stansiyalari va kichik GESlar, gidroenergetik qurilmalarning texnik-iqtisodiy hisoblari haqida umumiy ma‘lumotlar berilgan.

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В учебнике рассматриваются гидравлические основы гидроэнергетики, комплексное использование водных ресурсов, типы гидроэнергетических и насосных станций, их основные параметры и оборудования, здания и сооружения, напорные трубопроводы, гидроаккумулирующие электростанции и гидроэлектростанции малой мощности, технико-экономические расчеты гидроэнергетических установок.

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The textbook describes the fundamentals of hydraulic hydropower, integrated water resources management, types of hydropower and pumping stations, their main parameters and equipment, buildings and structures, pressure pipelines, pumped storage power plants and hydroelectric power plants of small capacity, feasibility study on hydropower facilities.

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INTRODUCTION

Mankind is constantly trying to solve three interrelated problems in its development. These include: food security; creating the natural and artificial environment necessary for normal life activities; power supplies.

In the current situation, the issue of electricity supply is in the forefront. The extent to which these issues are addressed effectively and efficiently is determined by the level of living standards of the population and, of course, the state of the environment. The increase in energy consumption is a product of the increase in the world's population and the improvement of its living conditions.

Modern energy is mainly focused on the use of minerals - coal, oil, natural gas. These sources are not permanent. Given the discovery of new mineral deposits, the supply of fossil fuels will be extended to 150 years. Therefore, the most optimal predictions are that the world's reserves of coal, oil and natural gas will be depleted in the near future.

In the 1970s, the global energy crisis sparked interest in the use of renewable energy sources in both developed and developing countries. In particular, it is one of the most important sources of renewable energy for hydropower today. According to the World Energy Conference, one-fifth of the world's electricity is generated by hydropower, which accounts for 20% of its total hydropower potential. Future utilization of hydropower potential remains a topical issue. This requires the construction of small, medium and large-capacity hydropower facilities in accordance with modern requirements. Such facilities will further increase the demand for qualified hydropower personnel.

Today, small hydropower plays an important role in the energy supply of countries and advantages of over large hydropower are recognized internationally.

Efforts to provide humanity with new energy resources will focus on the use of nuclear and thermonuclear energy. Until recently, nuclear energy was considered inexhaustible and environmentally safe. However, the "experience" gained during the study of the use of "safe atoms" does not guarantee that even the operation of the most modern nuclear power plants will not cause accidents not only locally, but also globally, catastrophically.

With the use of fossil fuels, nuclear and thermonuclear energy, the technological processes of energy production are accompanied by harmful emissions and increase the "thermal effect" of the environment.

In order to find seemingly high-level and universal energy technologies, humanity has moved away from the energy sources it used in previous eras - solar and terrestrial energy. The only alternative for conventional energy producers is non-conventional and renewable energy sources. These are endless and environmentally friendly. Experience in the study of renewable energy sources - wind energy, solar energy, biomass energy, hydropower, geothermal energy, etc. - has shown that the technology of their use is currently effective.

Hydropower is one of the most developed industries based on renewable energy sources. The industry is divided into traditional hydropower and small hydropower.

The main advantage of hydropower is the low cost of energy obtained. Non-use of fuel in the process of generating electricity has a positive economic and environmental impact.

Intensive development of small hydropower is taking place in the following way. The reports confirmed the relatively high performance of small hydropower plants. For example, the cost of installed power of 1 kW small hydropower plant is 1.5-2 times lower than the standard values obtained by wind farms and photo equipment.

The world's hydropower potential is more than 2,200 GW. Data on hydropower resources and their use in different regions of the world are given in Table 4.3. The table shows that hydropower is widespread in developed countries. In developing countries, the unused share of total hydropower resources is 90%.

In the Republic of Uzbekistan, on the basis of energy development, a large-scale work is being carried out to ensure full and quality supply of electricity to the economy and the social sphere.

Resolution of the President of the Republic of Uzbekistan dated May 2, 2017 "On the program of measures for further development of hydropower in 2017-2021", May 26, 2017 "On further development of renewable energy in 2017-2021, diversification of the balance of fuel and energy resources on the basis of extensive use of renewable energy sources, i.e. the transition from traditional fuels to renewable energy types. Much attention is paid to reducing their contribution to the production of electricity and heat through replacement.

In particular, the program of measures for further development of hydropower in 2017-2021 includes "implementation of modern and sound scientific and technical solutions in the design and construction of large, medium, small and micro hydropower plants, thereby increasing the share of hydropower capacity in the energy balance" provided.

The natural geographical conditions of the country and the state of water resources require the use of more small hydropower plants in the development of hydropower. With this in mind, it is planned to build small hydropower plants with a total capacity of 349 MW, each with a capacity of 2.0 ... 30 MW, out of 42 hydropower plants planned to be built in 2017-2021. As a result, the hydropower capacity of the country will increase 1.7 times.

At the same time, some work is being done in the country on the use of micro-hydropower plants.

According to the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan dated September 14, 2017 № 724, pilot projects of 37 microHPPs with a total capacity of 6100 kW are being implemented in canals, streams, ditches, reservoirs.

The goals set in the field of energy development of the Republic of Uzbekistan envisage increasing the share of renewable energy sources in energy production by 20% by 2025, and halving the energy capacity of production by 2030. The main part of the work to achieve these goals is the contribution of small hydropower, so the training of modern personnel in this field is one of the most pressing issues today.

Hydropower is one of the main branches of energy, which is the technical science of water and its methods of production and use for electrical purposes. Hydropower is closely linked to water management, providing integrated use of water resources as needed and in various sectors of the economy.

Hydropower as a science deals with hydropower devices - hydropower plants, pumping stations (when operating in turbine and pump power mode), hydroaccumulation power plants and hydroelectric power plants, hydraulic and hydrological, hydrotechnical and energy.

The training of specialists in higher education institutions begins with the introduction of the course "Introduction", and a student will have a full impression of his future hydropower activities. In addition, students will learn about general energy and ecology.

CHAPTER I. ENERGY AND ENERGY SOURCES

1.1. General concept of energy

Energy is work done in a unit of time. Natural phenomena are the basis of human culture and life. Energy, in turn, is a quantitative measure of the types of motion of matter, its transformation from one form to another. Energy is divided into mechanical, chemical, electrical, nuclear, etc.

From an energy point of view, there are the following units of measurement:

1 t.o.c. = 10 Gkal = 41,868 GJoul = 11,63 MW·hour;

1 t.o.e. =1 231 m^3 gas=1,04 ton of fuel oil=3,04 ton of coal;

1 t.c.f. = 862 m^3 gas = 730 kg fuel oil = 2,13 ton of coal;

1 t.c.f. = 0,7 t.o.e. = 29,3076 Gjoul;

1 t.c.f. = 7 Gkal = 8,141 MW·hour;

1 kWh = 3,6 MJoul = 0,86 Mkal = 0,0909 o. m^3 gas;

1 Mkal = 4,1868 MJoul = 1,163 kWh = 0,1057 n. m^3 gas;

1 MJoul = 0,2778 kWh = 0,2389 Mkal = 0,0253 n. m^3 gas;

1 t.c.f. = 7 Gkal = 29,3076 GJoul = 8,141 MW·hour.

Figure 1.1. Structural scheme of using energy resources during 1850–2027: 1-hydropower; 2-atomic energy; 3-natural gas; 4-oil; 5 -coal; 6-forest (wood) fuel.

A structural scheme of the use of energy resources around the globe from 1875 to 2027 is given in Figure 1.1. In this 1-hydropower; 2-nuclear energy resources; 3-natural gas; 4-oil and compressed gas; 5-Coal 5; Figure 6 shows the distribution of forest (wood) fuel resources. An estimate of the world's fuel resources is shown in Figure 1.2.

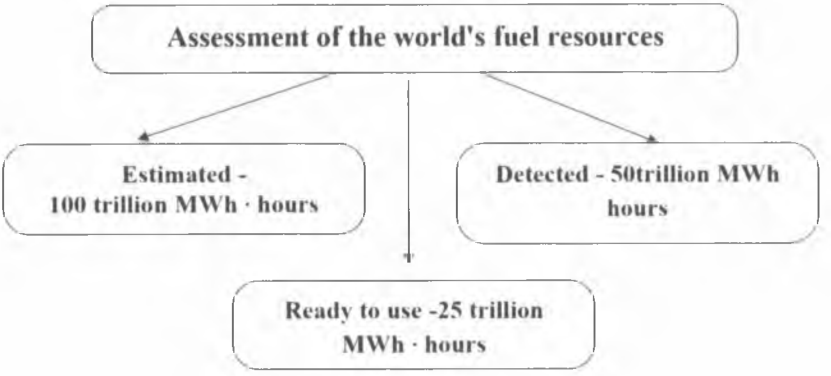


Figure 1.2. Evaluation of the world's fuel resources

Rapid development of the fuel and energy sector has become a priority of our state policy.

Electricity is a basic sector of the economy of the Republic of Uzbekistan and has a specific source of production and science and technology, which has a significant impact on its development.

The Republic of Uzbekistan has sufficient energy resources for the production of electricity and heat, as well as for use in industry, agriculture and all sectors of the economy, as well as in public life. At present, the production of energy resources exceeds the domestic demand by 15-20%.

The development of energy in the country began with the construction of the Bozsuv HPP near Tashkent (Figure 1.3). With a capacity of 4,000 kW, the station was commissioned in May 1926.

The construction of power plants on the Chirchik-Bozsuv tract continued at a rapid pace, and from 1926 to 1940, 67,000 kW of power was put into operation in this direction.

In 1940, the installed capacity of power plants in Uzbekistan was 170.5 thousand kW, generating 482 million kWh of electricity. kWh. Of this, 200 mln. kWh was produced in hydraulic power plants.

In 1940, the country's electricity generation was 72.5 kWh, but by the 1990s it had risen to more than 220 kWh.

Figure 1.3. It was first built in Uzbekistan in May 1926 Bozsuv HPP.

Uzbekistan's energy system generates $ 60 billion a year. It has the capacity to produce about kWh of electricity with a total installed capacity of 12.3 million kWh. There are 39 thermal and hydraulic power plants with a capacity of 1 kW (Figure 1.4)

Figure 1.4. Electricity network of Uzbekistan.

In 14 major cities of the country, consumers are provided with centralized heat energy. The total installed capacity of water heating boilers is more than 250,000 GJoules.

In recent years, Uzbekistan has become one of the world's ten largest oil and gas producers. Since 1997, 50 billion dollars have been spent annually in the country. 8 mln. tons of oil, ranking second and fourth among the countries of the Commonwealth of Independent States. Uzbekistan is the eighth largest gas producer in the world.

Uzbekistan has the highest energy potential in the Central Asian region. Over the past 30 years, 55-60 billion kWh of electricity was generated and the production capacity increased more than 3 times in the country. The largest thermal and hydraulic power plants in the Republic of Uzbekistan are listed in Tables 1.1 and 1.2.

Table 1.1

Large heat power plants in the Republic of Uzbekistan

№	Power plant	Aggregate capacity (MW)	Number of aggregates	Power plant installed capacity (MW)
Thermal power plants				
1	Syrdarya ThPP	300	10	3000
2	Yangi-Angren ThPP	300	7	2100

3	Toshkent ThPP	150/155/165	6/3/3	1860
4	Navoiy ThPP	25/50/60/150/160/210	2/2/1/2/2/2	1250
5	Taxiatosh ThPP	100/110/210	2/1/2	730
6	Angren ThPP	52/52.5/53/54.5/68	1/1/1/1/4	484
7	Fergona ThPP	25/50/55/100	1/1/2/2	305
8	Talimarjon ThPP	800	4	3200

On average, Uzbekistan's conditional fuel reserves have a unique potential of about 14 billion cubic meters. tons of conventional fuel. The volume of proven hydrocarbon reserves in Uzbek mineral deposits, on average, is 594 million tons worldwide barrels of oil and 1.9 trillion m^3 is equal to the gas.

Table 1.2

Large-capacity hydraulic power plants in the Republic of Uzbekistan

№	Power plant	Aggregate capacity (MW)	Number of aggregates	Power plant installed capacity (MW)
Hydraulic power plants				
1	Chorbog HPP	150/155/165	2/1/1	620
2	Xodjikent HPP	55	3	165
3	Tuyamoyin HPP	25	6	150
4	Andijon HPP	35	4	140
5	Farxod HPP	30/33	2/2	126
6	Gazalkent HPP	40	3	120

It should be noted that the balance of total consumption of energy resources in Uzbekistan over the past decade is 84-87% of natural gas, 11-8% of fuel oil and 3.5-4.4% of coal. It is obvious that the fuel does not meet the requirements of energy security in the form of energy balance. It is known that oil and gas reserves in Uzbekistan, as in other countries, are declining, which can last for several decades, while coal reserves can last for more than 250 years. In conclusion, given the low role of today's coal in Uzbekistan's energy, it is necessary to work to increase it. The diversification plan for the fuel and energy balance by 2015 envisages an increase in coal production to 11.0%.

Uzbekistan is a country with sufficient energy resources. At the same time, the consumption of natural gas and oil reserves shows that they can meet the needs of the country for decades to come. However, by this time, the amount of electricity consumed in the country could double to 50 billion kW, and non-renewable energy resources with conventional hydrocarbons are not enough to produce it. Given the necessary changes in the future, it is necessary to think today about the development of so-called renewable energy sources. These include hydropower, solar, wind, nuclear and biomass energy.

Given the future changes in energy suppliers, and environmental challenges in Central Asia and Uzbekistan, as well as the projected growth in energy consumption, especially in rural areas, there is no doubt that renewable energy needs to be developed.

Renewable energy is becoming more and more popular in the face of the global energy crisis. This is stated by Islam Karimov, the first President of the Republic of Uzbekistan, in his book "The Global Financial and Economic Crisis, Ways and Measures to Overcome It in Uzbekistan" as one of the surest ways for Uzbekistan to overcome the crisis and reach new heights in the world market. They stressed the need to modernize, reduce energy consumption and implement an effective energy saving system, which depends on how efficiently we can use available resources, primarily electricity and energy resources. Currently, fossil fuels - coal, oil, natural gas and uranium - are the backbone of the world's energy balance. At current levels of energy consumption, the world's oil reserves could last for 45-50 years, natural gas for 70-75 years, coal for 165-170 years, and lignite for 450-500 years. If the future development of the economy, population growth and the existing traditional energy supply is taken account, energy supply will increase accordingly. In addition, the use of fossil fuels has a negative impact on the environment. The country's energy sector emits more than 80 percent of its toxic emissions.

The world is showing great interest in the use of non-conventional energy sources. Non-traditional and renewable energy sources (NRES) are environmentally friendly because they do not emit pollutants into the atmosphere. In Uzbekistan, the use of small hydropower, solar, wind, biomass resources and geothermal energy is relevant. In addition, renewable energy sources may be the only economical, easily accessible source of energy for remote, mountainous, and inaccessible areas.

In the context of gaining independence, in order to ensure energy, environmental, economic security, as well as changes in the fuel, electricity and water systems, the widespread use of NRES for the development of energy in the country. The development of the fuel, electricity and water systems in our country should be a strong factor.

Uzbekistan is taking steps to develop NRES and promote its political and economic support. There are a number of regulations in place for the use of NRES. In particular, Article 20 of the Law on Rational Use of Energy, adopted on April 25, 1997, defines the legal limits for the general use of NRES. In addition, at the meeting of the Cabinet of Ministers of the Republic of Uzbekistan on February 13, 2009 in the program of modernization of electricity to ensure energy security of the country for 2009-2013, non-conventional and renewable energy the main role of the use of a number of large-scale projects have been implemented in the country by international sponsors and financial institutions, as well as a potential scientific and technological base for the production and maintenance of NRES.

The state policy in the field of renewable energy in Uzbekistan is based on the development of industry, as well as the experience and scale of development of renewable energy in a number of developing countries. This indicates that the establishment of clear goals and objectives in the field of renewable energy, as well as government support, will make renewable energy more competitive than traditional energy production technologies.

The current importance of the use of renewable energy resources in Uzbekistan is that, apart from hydropower, its resources are currently not widely used (on an industrial scale). It, like all new technologies, is in the research, development and experimentation phase of NRES, and needs to be economically and legally supported.

In recent years, monitoring of laws, government decisions and instructions have shown that the existing legal and regulatory framework in the field of NRES in the Republic of Uzbekistan, recycling and additions, economic and financial mechanisms and renewable energy sources should be reflected in the management mechanism that supports the development of use.

These laws should include a number of incentives to promote new resource-saving and environmentally friendly technologies, modern equipment and, most importantly, a high level of energy supply, both in production and in everyday life.

Resolution of the President of the Republic of Uzbekistan PP-2947 of May 2, 2017 on the program of measures for further development of hydropower for 2017-2021, was adopted in order to effective use of hydropower potential of the republic, to increase the share of renewable hydropower resources in the structure, to create new environmentally friendly production facilities and technological re-equipment of existing hydropower plants.

It is worth noting that the total number of hydropower plants has an average annual capacity of 5.2 billion kilowatt/hours. 28 of them are part of Uzbekenergo, 8 hydropower plants with an average annual capacity of 1.3 billion kilowatt/hours of electricity are owned by Uzsuvenergo under the Ministry of Agriculture and Water Resources.

.Such a division does not ultimately provide the necessary integrity for the technical management of the hydropower sector.

In accordance with the Decree of the President of the Republic of Uzbekistan, in order to form a unified system of water and energy management of the country, to consistently attract foreign investment in the development of hydropower and on this basis to ensure full satisfaction of electricity needs of enterprises and the population Uzbekhydroenergo JSC (Joint-Stock Company), which was previously part of Uzbekenergo JSC, as well as uniting all hydropower plants owned by Uzsuvenergo Association of the Ministry of Agriculture and Water Resources of the Republic of Uzbekistan to be established.

Uzbekhydroenergo has the following important tasks:

– implementation of a unified technical policy in the field of electricity generation at hydropower plants, ensuring safe and efficient operation of hydraulic structures, as well as centralized technological management of hydropower facilities;

– development and implementation of programs for the development of the hydropower sector on the basis of integrated development of hydropower potential, ensuring an increase in the share of hydropower in the energy balance of the country;

– implementation of investment projects for the construction and modernization of existing hydropower plants on the basis of modern and comprehensive scientific and technical solutions in the design and construction of large, medium, small and micro hydropower plants;

– development of cooperation with international companies and financial institutions to attract foreign investment and advanced technologies in the implementation of projects for the construction and modernization of existing hydropower plants;

– ensuring a balanced approach to the water potential of the country, the preservation of existing flora and fauna in the construction and operation of hydraulic structures, as well as the effective management of water resources, taking into account the climatic, natural and other characteristics of the country;

– systematic training, retraining and advanced training of personnel with higher and secondary special education in the field of hydropower.

In turn, Uzbekhydroenergo JSC was instructed to take measures to further develop hydropower in 2017-2021, approved by the President of the Republic of Uzbekistan on May 2, 2017 No. PP-2974. It should be noted that the functions of the executive and responsible bodies for the timely and quality implementation of the program are assigned.

In order to ensure the stable and reliable operation of the energy system of the country, the following rights of Uzbekenergo JSC have been preserved:

– integrated coordination of operational dispatch management of Uzbekgidroenergo enterprises through the existing National Dispatch Center;

– one hundred percent purchase of electricity generated by the enterprises of Uzbekhydroenergo JSC.

The structure of Uzbekgidroenergo JSC established by the Resolution of the President of the Republic of Uzbekistan "On the organization of activities of Uzbekgidroenergo " approved within the implementation of the decree was approved and its charter capital was approved. Relevant assignments were given regarding the formation and approval of the founding documents.

Uzbekgidroenergo has been allowed to set up consortiums and specialized subsidiaries in the country and abroad, including with leading foreign engineering, consulting and construction companies, to jointly implement investment projects.

According to the decision, Gidroloyiha JSC received a project on investment projects of Uzbekgidroenergo JSC and was appointed chief designer for the development of design documentation. In addition to investment projects implemented on the terms of international financial institutions and donor countries, the functions of the general contractor for the construction and modernization of facilities of Uzbekgidroenergo JSC are assigned.

In turn, Gidroloyiha received a project in the framework of investment projects for the construction and modernization of hydropower facilities in consultation with Uzbekgidroenergo and received the best local and project documentation. The right to involve foreign specialized design and engineering organizations, as well as leading specialists and experts, as subcontractors, on a contractual basis, coordinating their work.

To determine the demand of the hydropower sector for qualified personnel with higher and secondary special education and professional training, and to train them in higher education institutions and professional colleges of the republic, regardless of their departmental affiliation. The functions of the responsible body have been transferred to Uzbekhydroenergo JSC.

Ministry of Higher and Secondary Special Education of the Republic of Uzbekistan, Center for Secondary Special and Vocational Education, Ministry of Labor of the Republic of Uzbekistan and other joint-stock companies "Uzbekgidroenergo" the following tasks were given for implementation in cooperation with the relevant ministries, departments and business associations:

• the list of areas of higher education and specialties, secondary special, vocational areas, professions and specialties in the training of qualified personnel for the hydropower sector, as well as the higher education institutions and professional colleges that train them clearly defining;

• critical review of educational standards, curricula and programs based on modern requirements and international experience, including compulsory training, internships in hydropower plants, hydraulic engineering and hydropower enterprises and organizations;

• taking into account the implementation of the Program for the further development of hydropower in 2017-2021, the qualification of the hydropower sector in the formation of quotas for admission to specialized higher and secondary special, vocational education institutions each year, takes into account the real demand for specialists;

• control over the employment of graduates of higher education institutions and professional colleges in enterprises and organizations in the field of hydropower in their chosen professions and specialties, as well as, above all, secondary special and vocational education providing practical mechanisms to increase the responsibility of heads of institutions.

Implementation of the Resolution and Decree of the President of the Republic of Uzbekistan will allow:

• First, to unite the material and technical base of all existing hydroelectric power plants in the country and the construction, installation, repair, commissioning, scientific design organizations that serve them in a single field of hydropower;

• Second, the organization of hydropower through the coordination of electricity generation, implementation of long-term strategy of safe operation of equipment and facilities of hydropower plants, dynamic development of the industry, improvement of legal and regulatory framework, training of highly qualified specialists; implementation of financial and technological management;

• Third, the use of modern technologies and equipment, their possible integration and standardization, the application of international scientific and technical achievements in the design, construction and control of hydropower plants, the optimal performance of high energy performance and hydropower plants to ensure order and efficiency;

• Fourth, the program of gradual development of hydropower, which will ensure the full use of hydropower resources in the country, the modernization and operation of existing hydropower plants, the construction of hydropower plants of various capacities to increase the share of hydropower in the energy balance of Uzbekistan implementation;

• Fifth, to ensure the integrated development of water and energy resources in the country through the existing natural potential and careful attitude to the environment, to use them rationally in the interests of energy, water management, irrigation, drinking water and socio-economic development of the regions;

• Sixth, practical training, development and education of qualified engineers and technicians who seek to acquire knowledge, skills and abilities, improve the quality of life in the field of hydropower, while promoting the prestige of high-tech labor activity .

Decree of the President of the Republic of Uzbekistan "On the establishment of the joint stock company" Uzbekgidroenergo "and" On the organization of the activities of the joint stock company "Uzbekgidroenergo" The decision is aimed at strengthening the energy independence of our country, the efficient and safe use of existing hydropower plants, the creation of a single hydropower sector in Uzbekistan through the creation of highly maneuverable and efficient new power generation organizations.

1.2. Energy sources

After 2020 UN experts estimate that 7 billion to provide food to more than one-third of the population, indicating the need to increase its production by another 1/3, providing a sufficient number of people with quality food requires a 2-3 fold increase in their production.

It is important to provide the growing population not only with food, but also with fuel and energy. In many developing countries, wood is used as a fuel. Currently, 54% of the world's wood is used for fuel.

This process is expected to have a negative impact on the development of civilization. So far, the world's population growth has outpaced the increase in agricultural production, which starvation level is estimated 0.5 billion of population, 1 billion while living at a low nutritional level.

Thus, the growth of the world's population poses challenges in many countries and affects their development and living standards.

Therefore, finding new energy sources, solving the problem of meeting human energy needs is the most pressing issue.

The concept of "energy" is the combination of energy sources - its practical application in all its forms, its use in industry and in everyday life.

Energy resources are the most important part of any country's economy.

Energy sources are divided into two types:

Non-renewable, their stock decreases over use. These sources include coal, natural gas, oil, nuclear fuel, and more.

Renewable, their stock is constantly replenished in a natural process. These include water, sun, wind, and more.

Proven non-renewable fuel reserves have an energy equivalent of $12.8 \cdot 10^{15}$ kWh, and by 2010 energy consumption could reach $160 \cdot 10^{12}$ kWh.

The world's hydropower resources are $33 \cdot 10^{12}$ kWh, of which about 9 · 1012 kWh are economically viable.

The potential reserves of these sources are given in Table 1.3.

Table 1.3

Worldwide non-renewable and renewable energy sources

Energy sources	Reserves, 10^{12} kW (fuel) · hours
Non-renewable	
Total	602364
Energy of combustible minerals	55364
Nuclear (uranium, thorium) energy	547000
Renewable	
Total	1032636
Solar energy	665000
Ocean From:	350218

Salinity gradient	350000
Biomass	88
Leakage	70
Carriage	26
The wave	22
Temperature gradients	12
Wind energy	17360
Geothermal energy (Up to a depth of 3 km)	25
Hydraulic energy	33

Uzbekistan covers 1/3 of Central Asia and most of its territory is located between the Syrdarya and Amudarya rivers.

Uzbekistan has sufficient fuel and energy resources - oil, gas, gas condensate, coal, hydropower, solar and wind energy.

Uzbekistan is currently the eighth largest producer of natural gas in the world. The explored gas reserves are 2.44 trillion m^3, of which 1.89 trillion m^3 is free gas.

Uzbekistan's oil wealth is estimated at 600 million barrels (82 million tons). Coal reserves are estimated at 4.4 billion tons.

The world's fossil fuels include 4,850 billion tons of coal, 1,140 tons of oil, 310 billion tons of natural gas, and a total of 6,300 billion tons of conditional fuel.

The potential reserves of these sources are given in Table 1.3.

Coal. Oil. Natural gas

An energy engineer should at least have a general idea of the world's fuel reserves. Different fuels have different energy concentrations, as shown in Table 1.4.

Coal. The world's geological reserves of coal, in conventional fuel, are estimated at 12,000 billion tons, of which 6000 billion tons belong to reliable reserves. The following figure gives an idea of the world's coal reserves and prospects for their use (Figure 1.5).

Modern equipment and technology allow to extract 50% of reliable coal reserves, which is economically justified.

Burning coal produces about 8.14 kWh / kg (29.3 MJoul) of energy.

Oil. Assessing the state of the world's oil reserves is of great interest to many. This interest is squeezing oil and coal into electricity generation in many countries. Today, transportation oil accounts for 90% of the world's energy consumption. The average values of the various elements in coal are shown in Figure 1.6.

Table 1.4

Energy efficiency of conventional fuels

Fuel types	Conditional fuel	Coal	Wood (dry)	Oil	Gas (propane)	Hydrogen
Specific energy storage capacity is 106 J / kg kcal / kg	29.3 7000	33.5 8000	10.5 2500	41.9 10000	46.1 10000	120.6 28800

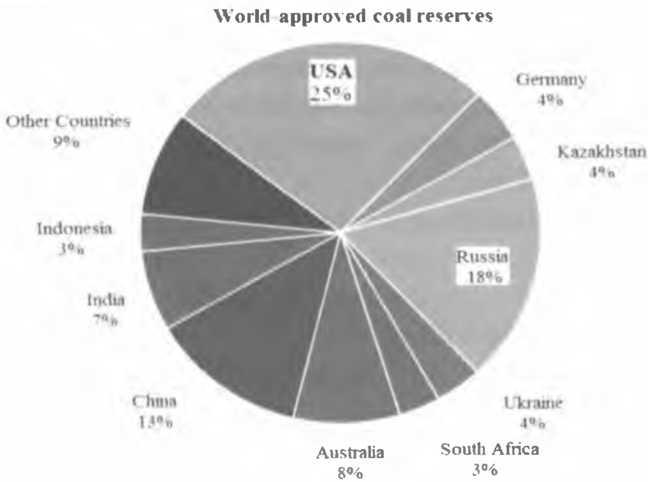


Figure 1.5. Values of world coal reserves.

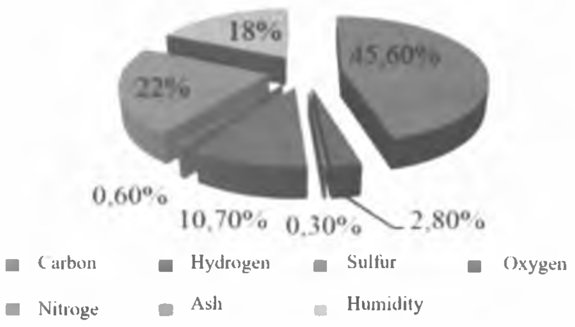


Figure 1.6. Approximate composition of coal.

The world's geological reserves of oil are estimated 200 billion tons, which 53 billion tons are included in reliable reserves. More than half of its proven oil reserves are in the Middle East. Developed Western European countries with the most skilled workforce have small oil reserves (Table 1.5).

Table 1.5

Small oil reserves in Western Europe

Country name	Reliable oil reserves of the world,%
USA	9.8
Latin America and the Caribbean	7.0
Canada	2.1
Western Europe	0.5
Africa	8.1
The Middle East	60.9

There are three main reasons for the rapid increase in oil consumption:

1) the development of all modes of transport (primarily automobiles and aircraft) for which there is currently no possibility to replace liquid fuels;

2) good performance of mining, transportation and use (compared to solid fuels);

3) switch to natural energy sources in a short time and at low cost.

Differences in the location of oil reserves and consumers have led to the development and expansion of oil transportation methods, such as the construction of large-diameter pipelines (larger than 1 meter) and large-capacity tankers.

Natural gas. The world's gas reserves are estimated at 140-170 trillion cubic meters m^3. The distribution of gas reserves by country is shown in Table 1.6.

Table 1.6

Distribution of gas reserves in Western Europe

Country name	Reliable gas reserves of the world,%
USA	27,5
Latin America and the Caribbean	6.2
Canada	4.3
Russia and Western Europe	14.4
Africa	15,1
The Middle East	20.6
Far East	2.3

Oil and gas are valuable not only as energy raw materials, but also as chemical raw materials. Currently, 5,000 synthetics are derived from oil and gas. However, only 3-5% of the reserves are used as chemical raw materials. Oil and gas fields are extracted from the ground and evaluated by drilling wells. Drilling costs account for 70% of geological and mining exploration costs.

Consumption of energy resources

Consumption of energy resources is growing rapidly and in line with world production. By 2005, energy consumption was 160,000 - 240,000 TVt hours (equivalent to 20 - 30 billion tons of conventional fuel). After 2005, the world's remaining energy reserves, excluding nuclear and thermonuclear energy, will reach another 100-250 years. This information is approximate, but it will shed light on some aspects of the future.The following figure shows the world's energy consumption.

By the year 2000, the world's total energy reserves will reach 20 billion tons of conventional fuel. In this system, oil and gas occupy a high place and production accounts for 3/5 of energy reserves; one-fifth is nuclear fuel and the rest is other solid fuels.

The 1960s saw significant changes in the structure of the world's fuel and energy balance. Consumption of liquid and gaseous fuels has increased. In 1980, oil accounted for 46% of the world's total energy consumption and gas for 20%.

By the end of the twentieth century, energy consumption was met by natural gas, coal and nuclear energy. Renewable energy efficiency is expected to increase at the beginning of the 21st century. It is estimated that the share of these energy reserves will be around 40% of nuclear energy. The largest share of available energy sources is coal (75-85%); oil (10-15%) and gas (10-15%) shares are significant; the remaining energy reserves together account for 2%.

Experts estimate that the world's total geological reserves are 200 million TVt hour, then using modern technological methods, 28,000 mln. TVt-hour fuel extraction has been found to be cost-effective. That's 380,000 times the amount of fuel produced in the world.

The world consumption of different energy carriers in relative terms over the years is shown in Figure 1.7.

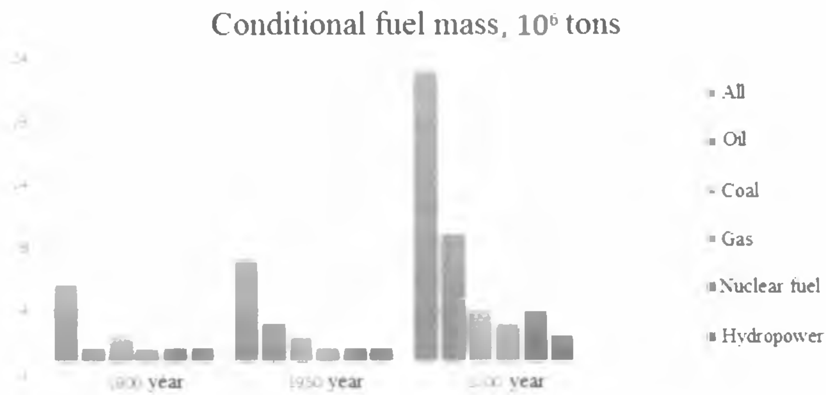


Figure 1.7. Conditional consumption of various energy carriers around the world over the years.

Most of the energy is used to generate electricity at power plants.

As a result of technological progress, humanity has a large amount of electricity, about 8-10 billion kW. If we take into account that power plants operate with an average 0.2 of UWC (useful work coefficient), it will take 40-50 billion kW power from nature to get the capacity they have.

Power varies from day to day and year to year. Power consumption is given graphically (Figures 1.8, 1.9).

If we replace the graph in the form of a rectangle with equal surface area, we get the maximum power duration Tm at the calculated value and find the energy used in the world. Based on the small value, we get the following result:

$E = 40$ billion kW $\cdot$ 5000 hours $= 200 \cdot 10^3$ billion kWh.

We convert this value to the conditional fuel. 1 ton of conventional fuel has a capacity of 8,000 kWh, which means that $200 \cdot 10^3$ billion will be needed to run power plants throughout the year. kWh / $8 \cdot 10^3$ kWh / ton = 25 billion tons.

Considering that there are 6 billion in our universe. 25 billion tons / 6 billion people=4.1 tons of energy reserves need per person during year.

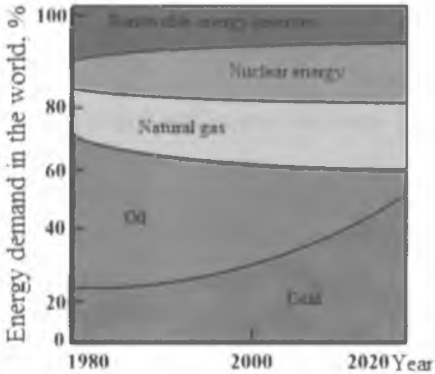


Figure 1.8. Worldwide fuel and energy reserves consumption structure.

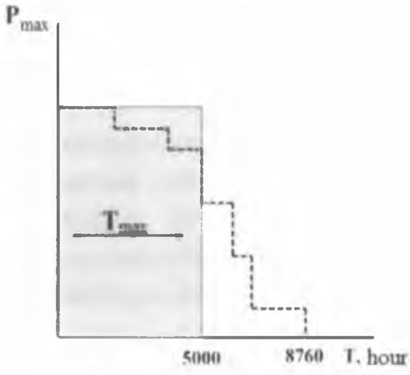


Figure 1.9. Graph of total power consumption of power devices.

1.3. Energy and ecology

On October 20, 1987, the 42nd session of the UN General Assembly adopted a resolution on "Sustainable Development". This means meeting the needs of the present generation without compromising the ability of future generations to meet their basic needs.

Irrational use of natural resources and pollution of the environment lead to the problem of human survival and the destruction of social and biological systems. This problem is also relevant for Uzbekistan, as its annual population growth is expected to increase by 400,000, with 60% living in rural areas.

Of this, 98% is recycled waste and has a negative impact on the environment.

It has been observed that the increased use of land and the demand for wood fuel have negative consequences not only for humans but also for the environment, especially for wildlife (Figure 1.11).

An analysis of the ecological situation and the state of environmental protection in Uzbekistan revealed that 52% of air pollution is caused by waste products from the production of fuel and energy facilities. Every year, they emit 700,000 tons of pollutants into the environment, of which 40,000 tons are solid and 660,000 tons are gaseous.

Table 1.7 shows the average levels of air pollution for ThPP (g / kWh).

In the Earth's atmosphere, carbon dioxide and its components, acid rain, deforestation, soil erosion and salinization are irreversible processes of radioactive and chemical pollution of water resources, which are the traditional non-renewable energy of organic mining. The division of resources is the result of the inefficient use of oil, gas, coal and others.

It is important to consider the concept of environmental reaction in fuel and energy production; the possibility of accidents at nuclear power plants, oil spills from the oceans and seas, methane gas emissions, etc., and emissions of harmful substances.

Due to this, the most important task in the environmental policy of any state is the rational production and efficient use of energy.

Table 1.7

Average levels of air pollution

Pollutant	Coal	Fuel types		
		Brown coal	Fuel oil	Natural gas
SO_2 solid particles	6,0 1,4	7,7 2,7	7,4	0,002 -
NO_2 fluorine compounds	2,1 0,05	3,45 0,11	2,45 0,004	1,9 -

The country's fuel and energy complex has been improving for many years and maintaining a conservative economic and resource structure, so one of the most pressing issues is to focus on economic, technological and social issues by making changes to their components and the use of natural resources with the necessary ecological cleanliness for the transition to new renewable energy sources.

The use of RES (solar, wind, small rivers, hot layer of earth, biomass, etc.) to ensure that their density, smallness and diversity to meet the needs of individual energy consumers more fully to perform energy supply for agricultural facilities can be used.

RES is considered to be environmentally friendly in terms of technology. In this sense, small hydropower and small hydroelectric stations have certain advantages over other types of RES.

The Spanish Association of Renewable Energy Producers and institutes and organizations have been working together to study the problems of energy and the impact of these resources on the environment in the production of electricity. This study is based on scientific methods to determine the number of environmental impacts: it takes into account the fact that electricity is obtained from different energy sources - lignite, coal, petroleum fuel, natural gas, nuclear fuel, solar photovoltaic cells and microHPP.

Depending on the power plants in question, the environmental penalty score is taken as a unit of measurement to compare the impact on the environment in the production of electricity. These scores are due to global warming, soil contamination, reduced sulphate oxygen content, heavy steel pollution, industrial waste, depleted energy resources, and so on.

The device that generates the most electricity (process) is considered to have the greatest impact on the environment. The results of the calculations are shown in Table 1.8 and Figure 1.10.

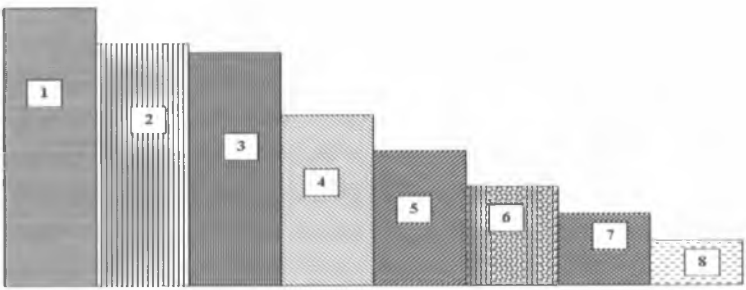


Figure 1.10. Environmental penalty points by the types of electricity generation.

As a result of these studies, the following conclusions have been drawn: environmental safety in RES power plants is much higher than in conventional power plants; RES has 31 times less impact on the environment than conventional energy sources (due to fossil fuels); 1

kWh of electricity is 300 times purer in a small HPP than the same 1 kWh of energy produced from lignite.

Micro HPPs do not have a significant impact on the environment, including emissions (SO_2, CO_2, NO_2) do not lead acid rain, soil flooding, climate change, ozone depletion, and etc.

At the same time, the use of small HPPs does not change the flora and fauna of the river and does not lead to the reduction of biodiversity. Small HPPs, such as Large HPPs, do not change the hydrological regime of agricultural lands due to water pressure. The effect of noise is unfavorable, as its magnitude ranges from 45 dB to 100-450 db. The biggest problem is the frequency of the noise below the audible level, which is less than 16 Hz, which produces an elastic wave.

Table 1.8

Environmental penalty points
by the types of electricity generation.

№	Fuel technology	Ecological penalty ball
1	Brown coal	1735
2	Petroleum fuel	1398
3	Coal	1356
4	Nuclear fuel	672
5	Solar photo element	461
6	Natural gas	267
7	Wind	65
8	Small HPP	5

These waves are absorbed insignificantly in the air and can travel long distances. At large amplitudes, noises can have a painful effect and have a strong effect on the psychology of living things.

Therefore, the lack of residential and industrial buildings in areas with strong wind potential, settlements, agricultural lands and recreation areas, transport networks, power lines, rivers, reservoirs, permanent bird habitats, national parks, etc. should be moved. One of the most noticeable limitations is the topography of the site, which makes significant changes in the structure of the wind flow and, consequently, impairs its physico-mechanical and geophysical characteristics. This makes the foundation for the WPD (wind power device) unreasonable and the wind turbine cannot be installed or the construction will be unreasonably expensive. These include turbid water pressure, sand heating, technological landslides, unstable landslides, floodplains, rocky areas, and more. In addition, the analysis of technical parameters of WPDs shows that their use is less effective in Uzbekistan. The operating speed of the wind speed is 9..10 m / s, and 5-6 m / s is required for the operation of the wind wheel. At the same time, it should be noted that in many districts of Uzbekistan the average annual wind speed is 3-4 m / s. This means that in order for the WPD to work effectively, it is necessary to work on special wind units and constructive technical solutions.

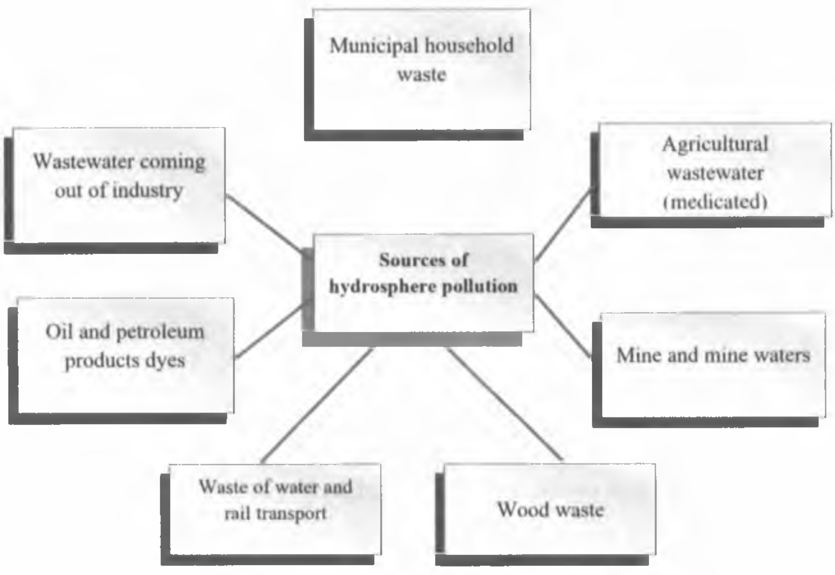


Figure 1.11. Sources of hydrosphere pollution.

In view of the above, and accelerating the design and construction of energy equipment is the most environmentally friendly electricity, which creates great prospects for production, and micro- and low-power renewable energy facilities through the use of unused reserves of water, wind, solar and biomass potential of Uzbekistan.

The width of water protection zones should be determined based on the function of reservoirs and other water bodies and the description of adjacent lands:

• large reservoirs and other reservoirs - with a capacity of 1.1 to 10 km^3;

• average reservoirs and other reservoirs - with a capacity of 0.6 to 1 km^3;

• small reservoirs and other reservoirs - with a capacity of 0.2 to 0.5 km^3;

• very small reservoirs and reservoirs with a capacity of less than 0.1 km^3.

Rivers can be grouped according to average annual water consumption as follows:

• large rivers - water consumption more than 100 m^3 / sec;

• medium rivers - water flow from 5 m^3 / sec to 100 m^3 / sec;

• small rivers - water consumption from 2 m^3 / sec to 5 m^3 / sec;

• very small rivers - water consumption up to 2 m^3 / sec.

Examples of water pollution are shown in Figure 1.12.

Figure 1.12. Water pollution.

Control questions

1. What are the units of energy in terms of power energy?

2. What types of large power plants are there in the Republic of Uzbekistan?

3. What are the sources of pollution of the hydrosphere?

4. How many tons of pollutants are released into the environment each year, of which how many tons are solid and gaseous?

5. What are the main reasons for the rapid growth of oil consumption?

6. What is the general concept of Bozsu HPP?

7. Tell us about the power grid of Uzbekistan.

8. How should the width of water protection zones be determined based on the function of reservoirs and other water bodies and the description of adjacent lands?

9. What are the groups of rivers according to the average annual water consumption?

10. What are the environmental penalty points for different types of electricity generation?

CHAPTER II. NON-RENEWABLE AND RENEWABLE ENERGY SOURCES

2.1. Renewable energy sources and their types

There are two types of energy sources:

Non-renewable – their reserves decrease during use. These sources include coal, natural gas, oil, nuclear fuel, and more.

Renewable – their reserves are constantly replenished in a natural process. These include water, sun, wind, and more.

Table 2.1 shows the world's non-renewable energy reserves.

Table 2.1

Renewable energy reserves around the world

Energy sources	Reserves, 1012 kW (fuel) · hours
Non-renewable	
Total	602364
Energy of combustible minerals	55364
Nuclear (uranium, thorium) energy	547000

Uzbekistan has sufficient fuel and energy resources. These are: oil, gas, gas condensate, coal, hydropower, solar and wind energy.

From 1990 to 1994, gas consumption in the country continued to grow due to the decline in coal production in the country and the decline in imports of coal and fuel oil. Coal consumption decreased from 9.2 million tons to 4.2 million tons during the period. Coal shortages are naturally covered by gas.

It is known that Uzbekistan is rich in hydrocarbon reserves. Natural gas, oil, gaseous condensate, and coal are sufficient to meet fuel needs for a period of time (Figure 2.1). The data are the values of the heat of combustion for different types of fuel (Table 2.2).

It is unsatisfactory to be supplied with oil and, accordingly, oil products in the long run. Uzbekistan's oil fields are mainly sulfur-rich (up to 25%) and contain large amounts of paraffin, as well as tar and asphalt. As a result, the oil recovery factor from the field is only 0.4.

Table 2.2

Combustion heat values of conventional fuels

Fuel type	Unit	Combustion heat			
		GJ	MWh	t.c.f	t.o.e
Equivalent to oil	T	41,868	11,630	1,42857	1.000
Fuel	T	40,61	11,281	1,38565	9,970
Diesel fuel	T	42,50	11,806	1,45014	1,0151
Kerosene	T	43,12	11,978	1,47129	1,0299
Gasoline	T	43,09	11,969	1,47027	1,0292
Liquefied gas	T	45,61	12,669	1,55625	1,0894
Coal	T	25,54	7,094	0,87145	0,6100
Coke	T	28,05	7,792	0,95709	0,6700
Charlie fuel	T	29,31	8,141	1,000	0,7000
Anthracite	T	33,48	9,300	1,14237	0,7800
Natural gas	1000 m^3	36,00	10,000	1,22835	0,8598
Mixed fuel wood	Skal. m^3	4,51	1,253	0,15388	0,1077

Brown coal from the main deposit (Angren) is a low-calorie high ash, containing various elemental additives, as well as radioactive. Therefore, both the extraction and recycling and incineration stages require special technology, as well as a set of equipment and special technologies for the use of harmful products such as ash, open rock, etc.

Therefore, it is important to involve autonomous, centralized energy sources, in particular, solar, wind, small water users, etc., in the energy balance, which also eliminates the need for conventional energy carriers (oil, coal, gas). It allows you to change places and solves environmental and social problems.

Uzbekistan is currently the eighth largest producer of natural gas in the world. The explored gas reserves are 2.44 trillion m^3, of which 1.89 trillion m^3 is free gas, the rest is in the form of mixtures, that is in the oil-soluble state and where the gas is concentrated in oil and gas deposits.

Uzbekistan's oil wealth reaches 600 million barrels (82 million tons), and coal reserves - 4.4 billion tons is formed.

The main advantages of renewable energy sources are incompleteness and environmental friendliness. Using them will not change the energy balance of the planet. These qualities contribute to the broad development of optimistic forecasts for the development of renewable energy both abroad and in the next decade. Renewable energy sources play a significant role in addressing three global challenges facing humanity: energy, the environment, and trade.

Solar energy. Photocells (complete conversion of solar energy into electricity) and systems are expected to explode at the base. In 1999, the annual power generation using photovoltaic cells was 200 MW. Leading countries - Japan-80, USA-60, Germany-50 MW (Russia-0.5 MW). The total surface area of solar water heaters (solar collectors), according to incomplete data, exceeds 21 million m^2 in the world, with annual production of solar collectors exceeding 1.7 million m^2. Leading countries: Japan-7, USA-4, Israel-2.8, Greece-2.0 million m^2 (Russia-0.1 million m^2). Table 2.3 shows the world's renewable energy reserves.

Wind energy. The installed capacity of wind turbines in the world increased from 6172 MW in 1996 to 12000 MW in 1999. Approximately 3,600 MW by 2006. Leading countries: Germany-4444 MW, USA-1819, Denmark-1752, Spain-1539, India-1100 MW (Russia-4 MW). The turnover of the wind energy industry in the world in 1998 amounted to 1.7 billion dollars, an increase of 31% over the previous year.

Table 2.3

Reserve of renewable energy sources around the world

Energy sources	Reserves, 10^{12} kWh (fuel) · hours
Renewable	
Total	1032636
Solar energy	665000
Wind energy	17360
Geothermal energy (<3 km)	25
Hydraulic energy	33
Ocean From:	350218
Salinity gradient	350000
Biomass	88
Flow	70
Carriage	26
The wave	22
Temperature gradients	12

Hydropower. The economic potential of hydraulic energy in the world is estimated at 8100 TVt.h. The installed capacity of all hydropower plants is 669 TVt, and the generated electricity is 2691 TV.h. Thus, the economic potential is used to 33%. China is the world leader in small hydropower, where from 1950 to 1996, the total capacity of small hydropower plants increased from 5.9 to 19,200 MW. In the next decade, China will be developing up to 100 MW per year. In India, at the end of 1998, the installed capacity of small hydropower plants (primary capacity up to 3 MW) was 173 MW; there are hydropower plants with a total capacity of 188 MW during the construction phase. Construction sites have again been identified around the overall design. Small hydropower plants in a number of European countries, including Australia, Finland, Sweden and others, are operating effectively.

Geothermal energy. The installed capacity of geothermal power plants (GPP) ranged from 678 MW in 1970 to 8000 MW in 2000 in the Philippines-1909, Italy-785, Mexico-755, Indonesia-589 MW (Russia-23 MW). Over the past 30 years, GPPs annual capacity growth has been 8.6 percent. The installed capacity of geothermal heat generators has increased from 1950 to 17,175 MW over the last 20 years.

Biomass energy. The use of biomass energy is carried out in several areas: the production of biogas, the use of energy from solid waste (DW), the use of wood fuel and peat.

Biogas and fertilizer production:

• The total amount is 6 mln. in small units for processing agricultural and household waste of private farms with more than one unit (this direction is especially developed in China and India);

• Mixed municipal and industrial wastewater treatment plants (100 new devices in the world) and large urban wastewater treatment plants (more than 10,000 devices);

• Factories for the processing of agricultural, livestock and farm products (more than 50 factories in Europe) are equipped with high-capacity mixed devices.

The biogas obtained from the above devices is used in domestic, water heaters and steam boilers, as well as in diesel generators that generate electricity.

Renewable energy resources of Uzbekistan

When assessing the role of renewable energy sources (RES), a well-known fact is the depletion of earth's fossil fuels, their all-accelerating consumption rates, and the need to look for alternative energy sources, as well as fuel and energy. It is necessary to take into account the implementation of strict procedures for saving resources.

Figure 2.1 shows the forecast of Uzbekistan's supply of hydrocarbons.

There are a number of scientifically and technically proven and, to some extent, competitive approaches to solving this problem. In the future, at a certain stage of development, there is a need to develop all areas of exploration for new energy sources, choosing the direction that provides the most economic efficiency.

One of the ways to solve socio-economic problems related to energy to one degree or another is the active development of local energy resources (small reserves of coal, gas, oil in areas with developed infrastructure), as well as large-scale use of environmentally friendly renewable energy sources available on the territory of Uzbekistan.

The concept of renewable energy sources includes the following forms of energy: solar, geothermal, wind, sea wave energy, currents, straits and oceans, biomass energy, hydro-energy, low-potential thermal energy and other renewable energy "new" species.

Conditionally, it is accepted to divide RES into two groups:

Typical: hydraulic energy converted into electricity by hydroelectric power plants with a capacity of more than 30 MW, biomass energy used to generate heat from wood, peat and other types of stove fuel by conventional combustion methods, geothermal energy.

Unusual: solar energy is wind energy, sea waves, currents, strait energy, hydraulic energy, which is the type of energy used by small and microHPPs, biomass energy that is not used to generate heat by conventional methods, low potential heat energy and other renewable energy "new" species.

The potential reserves of RES will be large, technical and economic. The average annual energy content of a RES when the total potential of a given type of RES is fully converted into useful energy.

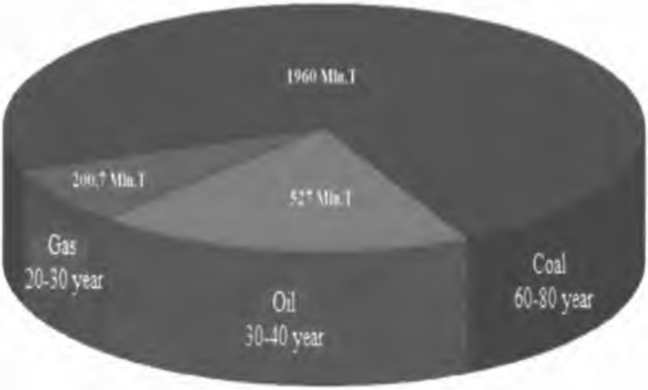


Figure 2.1. Forecast of Uzbekistan's supply of hydrocarbons.

The technical potential of RES is part of the potential, and its conversion into useful energy will be possible at a given level of development of technical means when it meets the requirements of environmental protection.

The economic potential of RES is part of the technical potential, which is economically feasible at the level of the cost of energy used, fossil fuels, heat and electricity, equipment, materials and transportation services, labor costs, and so on.

Generalized data on the general and technical potential of renewable energy sources of Uzbekistan, based on the results of design and survey, research work of NGOs, organizations and enterprises of the Republic of Uzbekistan, the scale use of renewable energy resources and fuel as a result of the gradual reduction of the share of the use of raw materials in the consumption and production of heat and electricity also shows the principled technical feasibility of meeting the needs of the republic in primary energy carriers (Figure 2.2).

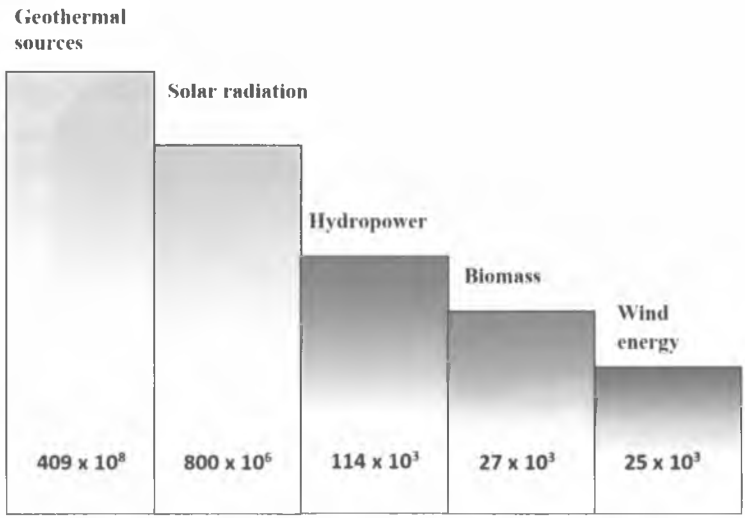


Figure 2.2. Potential energy reserves of renewable energy sources within the territory of Uzbekistan (million kWh / year).

The assessment of potential reserves of renewable energy sources shows that they are very high in the country.

The annual potential of solar energy, small rivers, wind energy and other sources within the territory of the republic is 55-60 million tons of conventional fuel, several times the annual demand for fuel and energy resources, and many times more than the discovered reserves of hydrocarbons.

Geothermal energy is the leading renewable energy source in terms of valleys or, in other words, theoretical reserves (Figure 2.3, Table 2.4). However, relatively low temperatures (up to 70-80°C), high mineralization of artesian water and depth of deposition make it technically difficult to use them for electricity generation. Therefore, if we look at the technical potential, solar energy is the leader. The cost of energy produced limits its widespread use.

Table 2.4

Potential indicators of renewable energy sources

	Solar energy (1)	Geothermal energy (2)	Hydropower (3)	Biomass energy (4)	Wind energy (5)
Total potential	0,76	99,24	$1{,}36\cdot10^4$	$3{,}4\cdot10^5$	$3{,}3\cdot10^5$
Technical potential	98,5	-	1,08	0,14	0,23
Economic potential	0,18	-	99,82	-	-

Therefore, of all the types of renewable energy sources, hydropower, which has a very high economic potential and currently stands at 14.4 billion kWh, is the most practical. Currently, only 4 to 6.5 billion kWh are used (Figure 2.3). Unused reserves are included in the group of small and medium-sized hydropower plants, which are classified by their relatively small pressures, resulting in low-capacity hydropower plants that run along the entire flow of water, including irrigation and drainage canals.

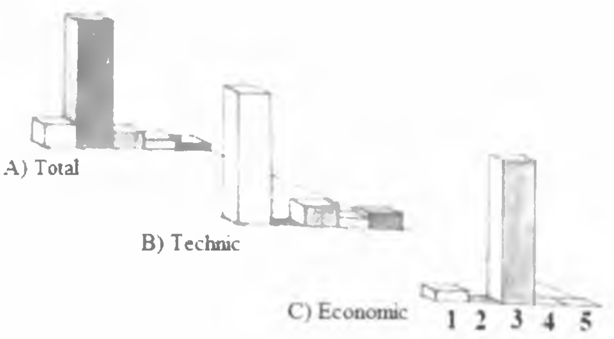


Figure 2.3. Renewable energy resources.

The overall increase in energy prices will make small and medium-sized HPPs more competitive. Experiments have shown that the use of different types of micro HPPs (sleeve, sleeveless, pole, etc.) is effective. The integrated use of water energy will help to solve the problem of energy supply to consumers who are less powerful in terms of absolute energy consumption, but very efficient in terms of production results. This is especially true in the foothills of settlements and arable pastures.

In areas of centralized energy supply, the use of local autonomous energy sources will create a competitive environment for the energy market. In addition to the energy of small and medium-sized streams, non-conventional energy sources (wind, solar, biogas energy) can also participate in such competition. According to preliminary estimates, the potential of small and medium water flows, local and non-conventional energy sources in absolute terms is from 1 to 1.5% of the total use of primary energy. Its social impact is not measured in terms of creating an environment for small and medium-sized businesses, improving living conditions in remote areas of the country (Table 2.5).

Table 2.5

Source capacity of renewable energy in Uzbekistan

Indicators	Total (mln.t.n.e.)	Including energy (mln.t.n.e.)			
		hydro	solar	wind	biomass
Gross	50984,6	9,2	50973	2,2	–
Technical	179	1,8	176,8	0,4	0,3
Assimilated	0,6	0,6	–	–	–

Part 1 falling or being formed in the designated territory theoretical energy.
Part 2 of the existing technology that can be used to realize the full potential.

2.2. Solar energy

Solar energy (SE) has been used by humans since ancient times. By collecting sunlight in 212 BC, they created a fire in front of mosques and temples. It is said that the great Greek scientist Archimedes used solar energy to liberate his city of Syracuse from the Roman navy and set it on fire.

In the upper layers of the Earth's atmosphere, the flux of sunlight is $1.78 \cdot 10^{17}$ W, and at the Earth's surface it is $1.2 \cdot 10^{17}$ W.

The distribution of solar energy at the Earth's surface is extremely uneven. The amount of solar energy per 1 m^2 of land per year corresponds to 3,000 MDj/m^2 in the northern regions and 5,000 MDj/m^2 in the hot light zones.

The density of solar energy is 1353 W/m^2 with respect to the plane perpendicular to the rays at the upper limit of the atmosphere, which is called the domain.

The average energy content is 4871 kDJ/s·m^2 per 1 m^2 of surface in E (Figure 2.4).

The maximum density of solar energy is 1 kWh · m^2.

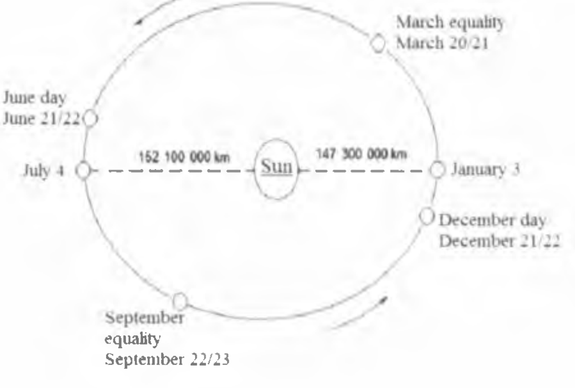


Figure 2.4. The rotation of the Earth's orbit around the Sun.

At the upper limit of the Earth's atmosphere, the sun's rays radiate at an absolute temperature of about 5,900 K.

It consists of ultraviolet light (wavelength l = 0.2… 0.4 μm), visible light (l = 0.4… 0.78 μm), and larger wavelength infrared rays (Figure 2.5).

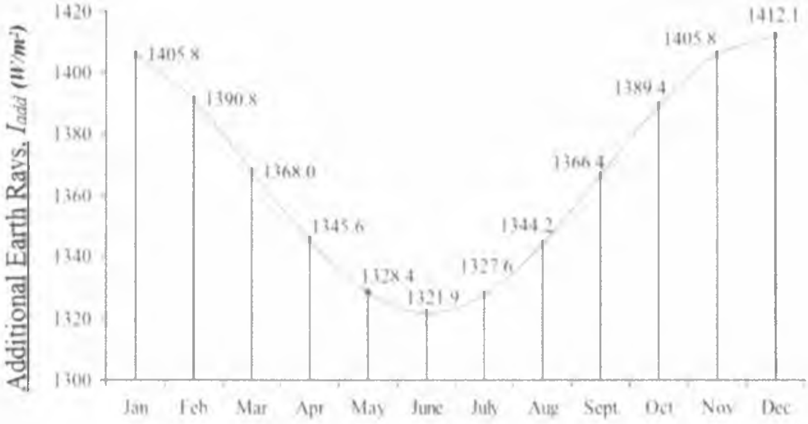


Figure 2.5. The duration of the annual change in solar energy.

Table 2.6

The duration of changes in solar energy by day and hour

Months of the year	Per day, W · s / (m² · day)	Hourly, W · s / (m² · day)						
		12	11,13	10,14	9,15	8,16	7,17	6,18
January, December	2860	710	670	630	540	310	-	-
February, November	3245	750	740	690	605	460	-	-
March, October	3920	780	770	730	670	650	320	-
April, September	4411	800	790	765	730	640	546	170
May, August	4640	800	790	765	730	670	545	340
June, July	4760	785	780	770	730	670	585	440

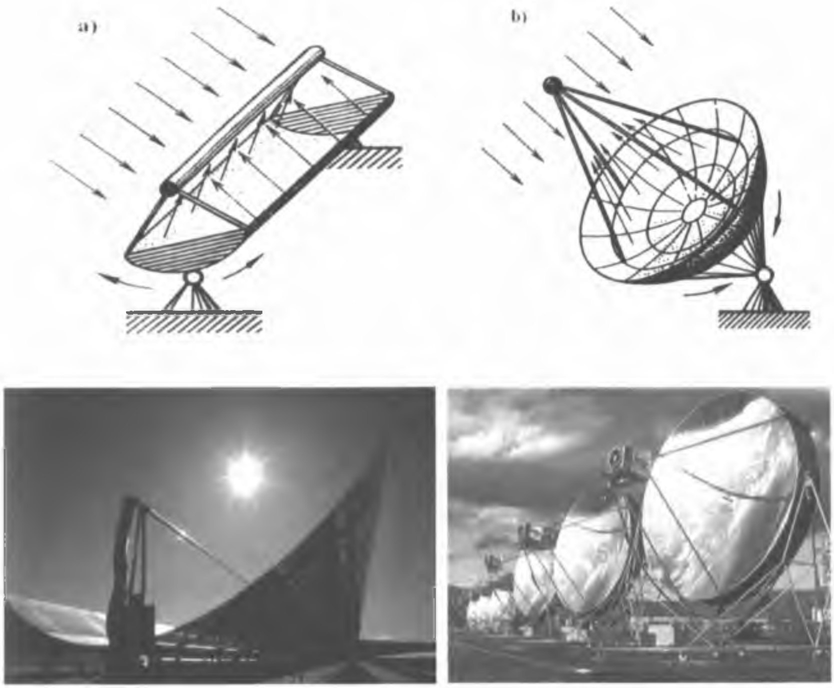


Figure 2.6. Scheme and picture of active solar system concentrators (a) is right-angled, b) is parabolic.

As the sun's rays pass from the atmosphere to the earth, some of the light is emitted and absorbed by ozone, air, water vapor, and dust particles and molecules. This reduces the intensity of direct sunlight and allows it to diffuse. Some of the energy goes back into space and some reaches the earth's surface (Figure 2.6). The proportion of scattered rays depends on climatic and geographical factors and varies throughout the year: 0.39 in Kiev in June, 0.75 in December, 0.54-0.8 in Moscow, 0.19-0.5 in Tashkent, and Ashgabat. 0.3-0.5.

The potential of solar energy can be characterized by the average annual amount of solar radiation per 1 m^2 of horizontal surface.

The annual flow of sunlight varies widely in the CIS. For example, 1 m^2 of horizontal plane in the latitudes of northern and northeastern Siberia 550-830 kWh per year, in most European regions 830-1100 kWh, in southern Ukraine, Moldova, along the Volga, Siberia, Far East 1100- 1300 kWh, in the Transcaucasus and Central Asia - 1400-1600 kWh, in the desert zone of Uzbekistan - 2000 kWh and more.

In Central Asia, the duration of a sunny day is 16 hours in June, 8-10 hours in December, and 300 days a year, the duration of a sunny day is 2500-3100 hours/year, and 320-340 hours/year in summer (Table 2.6).

At present, the methods of using SE have reached high technological sophistication, are used in effective and extensive practical work in different climatic conditions (Figures 2.7, 2.8). The use of SE can be divided into two groups:

1) use of direct solar radiation;

2) secondary, i.e. in the secondary form of solar radiation, use in the form of wind, ocean heat, biomass reserves, hydropower, and etc.

Direct use of SE, in turn, reduces solar radiation can be used in the following methods:

– heat;

– photoelectric;

– thermoelectric.

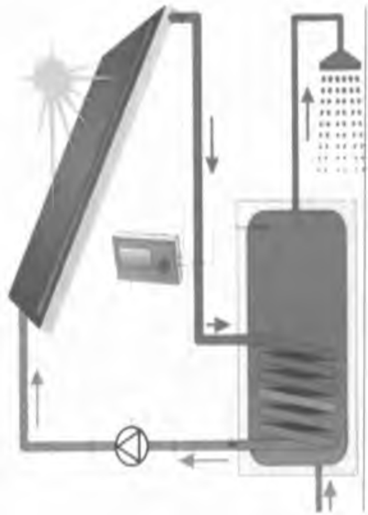


Figure 2.7. Heat method scheme.

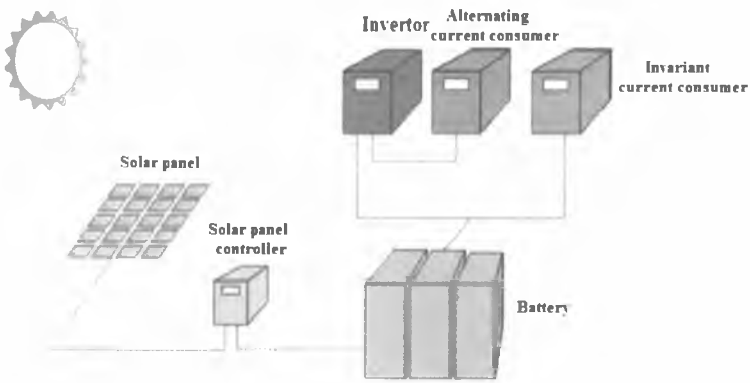


Figure 2.8. Photoelectric method scheme.

A simplified scheme of a solar power plant (thermo-electric methods) is shown in Figure 2.8. A simplified scheme of obtaining electricity through heat accumulators is shown in Figure 2.9.

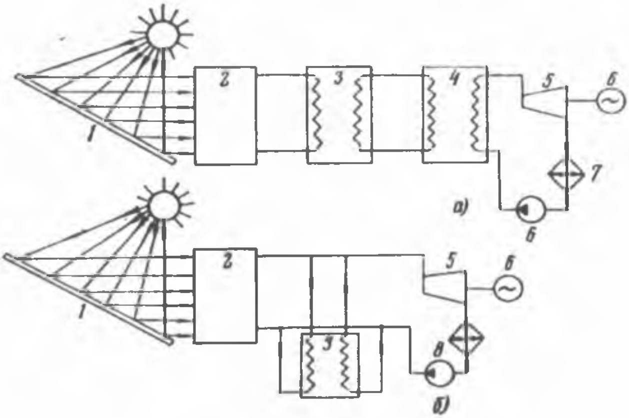


Figure 2.9. Simplified schemes of solar power plant:
a) the appearance of the heat accumulators in series;
b) appearance of heat accumulators in parallel:
1 -sunlight trap; 2- receiver; 3-heat accumulator; 4-temperature changer; 5- steam turbine; 6-generator; 7-capacitor; 8 -condensation pump.

The "solar sail" is used to move spacecraft due to the pressure of sunlight on the glass surface.

Figure 2.10. Sun sail view.

Thermal air power plant (Solar aerostatic power plant) - converts solar energy into a stream of air that is directed to a turbogenerator.

Figure 2.11. Solar aerostatic power plant.

Solar wells to illuminate their buildings. Solar wells were first developed in Australia in 1991 under a patent obtained in 1986.

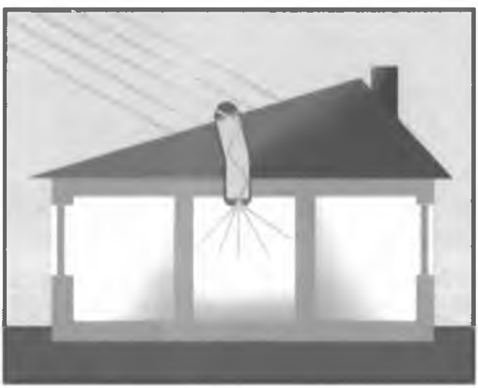


Figure 2.12. Solar well diagram.

Upper part **Lower part**

Figure 2.13. Solar well installed to the underground station in Berlin.

The largest solar thermal power plant in the world is Solar Energy Generating Systems, located in California, USA.

With a capacity of 354 MWh, it consists of 9 small power plants:

• 6 - 30 MWh, total 180 MWh;

• 2 - 80 MWh, total 160 MWh;

• 1 - 14 MWh, total 14 MWh.

These nine power plants are spread over the Mojave Desert in California, covering an area of 6.5 km2 and using 936,384 parabolic concentrators.

The world's largest solar photovoltaic plant is located in Finsterval de, Germany and is called Finsterwalde Solar Park.

Its capacity is 80.7 MWh.

Formerly known as Olmedilla Photovoltaic Park in Spain with a capacity of 60 MWh.

Currently, 97 MWh solar photovoltaic power plants are under construction in Canada (Sarnia PV power plant) and 84.2 MWh in Italy (Montalto di Castro PV power plant).

Figure 2.14. The world's largest-capacity solar thermal power plant, Solar Energy Generating Systems, is located in California, USA.

Figure 2.15. Located in Finstervalde, Germany, it is the world's largest solar photovoltaic plant called Finsterwalde Solar Park.

2.3. Wind energy

Wind is caused by uneven heating of the earth's surface. In this case, the hot air layer moves up, and the cold layer moves down.

In the last 10 years, the world's wind energy (WE) has developed tremendously. The average annual capacity of WE devices (WED) was more than 32%.

So far, no energy sector has developed to such an extent. Table 2.7 shows the geographical distribution of WED. This takes into account the nominal capacity of the WE is 1 MW and more. Leading the way are European countries and the United States, which have been focusing on the development of WE in these geographical locations since the 1980s. This type of energy is also receiving a lot of attention in developing countries, as it is clearly proving that these countries have limited fuel and energy resources.

A wind energy cadastre will be developed to determine and effectively use wind parameters for each region. The main characteristics of WED include:

– average annual wind speed and its daily rate;
– velocity repeatability, its type and parameters;
– maximum wind speed;
– wind cycle distribution and duration of the energy cycle;
– specific wind power and energy;
– regional wind energy resources.

Wind resources are obtained from climate data based on static analysis of average wind speeds and their standard anemometric height (10 m above ground level).

In determining wind irregularities for each month, the effects of local influences on wind strength and direction are studied, taking into account geography, roughness, hilly terrain, its openness, altitude, and so on.

The fact that wind energy is not constant, and that it is monitored at different levels in the field, in real life, determines its potential, such as special work, site selection and installation of WED.

In Uzbekistan, the prospects of WE can be realized at the expense of small devices with a capacity of 1-5 kW.

Table 2.7

Geographical distribution of wind energy device

Countries	MVt	Countries	MVt
Germany	6107	Brazil	20
Spain	2836	Belgium	19
USA	2610	Turkey	19
Denmark	2341	Luxembourg	15
India	1220	Argentina	14
Netherlands	473	Norway	13
England	425	Iran	11
Italy	424	Poland	11
China	352	Tunisia	11
Greece	274	Australia	30
Sweden	265	South Korea	8
Japan	142	Israel	8
Canada	139	CIS	20
Ireland	122	New Kaledoniya	4.5
Portugal	111	Czech Republic	4
Austria	79	Sri Lanka	3
Egypt	68	Switzerland	3
France	63	Mexico	1,6
Marokash	54	Jordan	1,2
Costa-Rika	51	Latvia	1
Finland	39	Other countries	1,7
New Zealand	35	Total	18449

This is due to the fact that the wind speed is 3-4 m / s in regions with large consumers, and 10-12 m / s in areas with high potential.

There are two types of wind turbines that convert wind energy into mechanical energy (Figure 2.16):

1. Horizontal wind wheel (winged) (2-5).

2. Wind wheel rotating on a vertical axis (carousel: paddle (1) and orthogonal (6)).

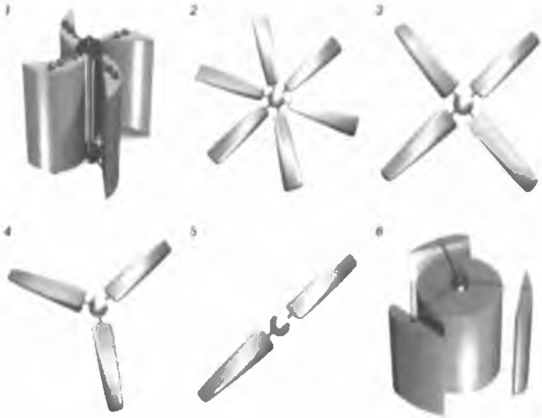


Figure 2.16. Types of wind wheels.

Figure 2.17 shows the WED view and Figure 2.18 shows the WED view.

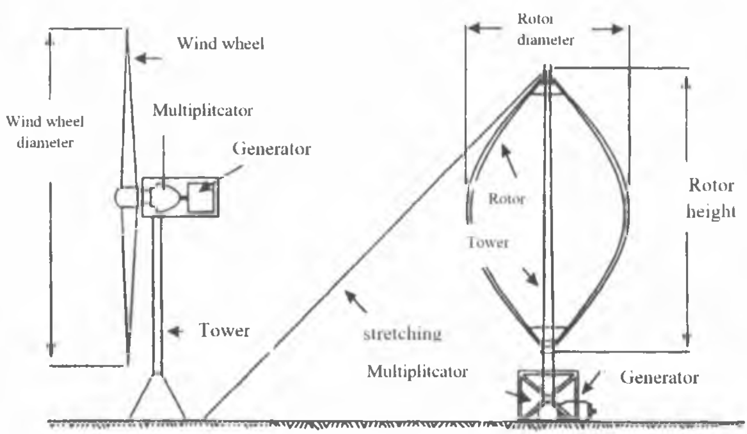


Figure 2.17. General view of WED.

Rotating wind wheel on horizontal axis

Rotating wind wheel on vertical axis

Figure 2.18. WED view.

The structure of a modern high-power wind turbine is shown in Figure 2.19.

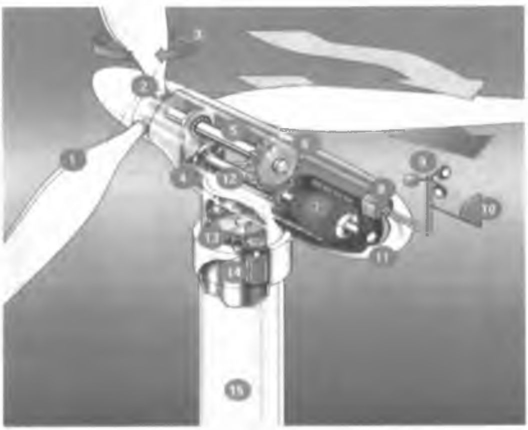


Figure 2.19. Modern large-capacity wind power plant structure.
1-paddles (feathers); 2-rotor; 3-paddle turning mechanism;
4 brakes; 5-speed shaft; 6-multiplicator; 7-generator; 8-controller;
9- anemometer; 10-windvane; 11-gondola; 12-speed walking shaft;
13 - gondola rotation reducer; 14-gondola engine; 15-tower.

WEs annual potential is very large. It is 100 times larger than the hydropower potential and is 3300 · 1012 kW · s. Only 10-12% of this can be used. The power distribution according to the wind power devices and the diameter of the impeller is shown in Figures 2.20 and 2.21.

Figure 2.20. Picture of wind power devices.

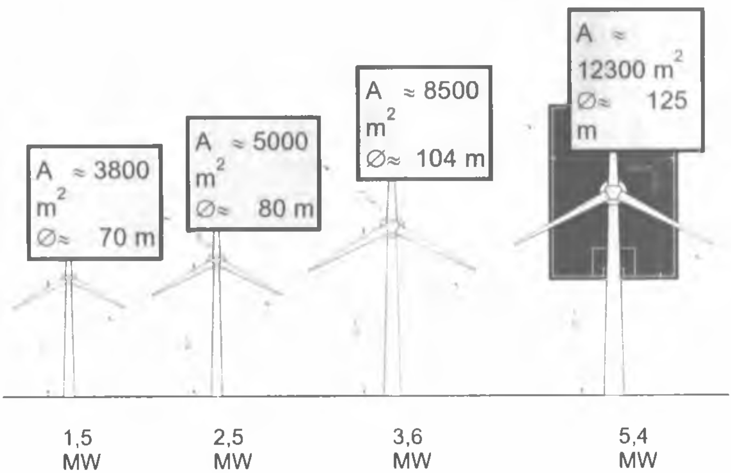


Figure 2.21. Power distribution of wind turbines according to the diameter of the impeller.

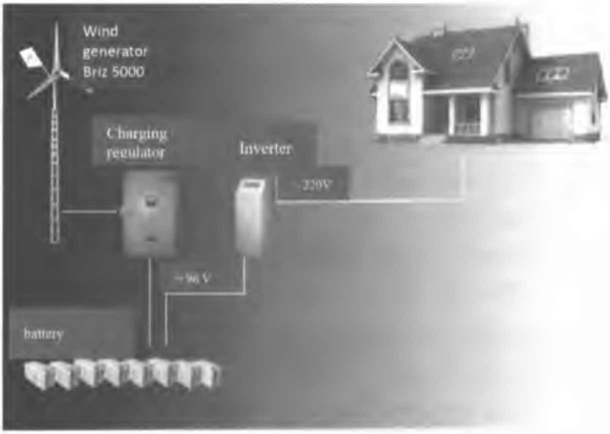


Figure 2.22. WED scheme for power supply of the apartment.

The WED circuit for powering the apartment is shown in Figure 2.22. In the calculation of wind current (WC) energy, the kinetic energy of a body of mass m is determined by the motion at velocity V.

In this case, the mass of WC is equal to W $E = m\frac{v^2}{2} = \rho W\frac{v^2}{2}$ is equal to ρ – air density.

Then the strength of the air flow per unit time is determined as follows:

$$N_n = \rho Qt \cdot \frac{v^2}{2z} = \rho F\frac{v^2}{2}.$$

WED power differs from WC power by its utilization factor S:

$$N_A = S \cdot \rho \cdot F_{sh} \cdot \frac{v^3}{2}$$

where -WED is the surface affected by the wheel.

$S = S_k \cdot \eta_g \cdot \eta_m$ determined from, S_k – WED wheel utilization factor;

η_g va η_m – generator and multiplicator u.w.c. (useful work coefficient).

Fast-moving wind turbines usually have many shovels (with 2 or 3 wings). The shovels are made of steel, aluminum, plastic or special wood to make them weatherproof, strong and light. These wind turbines are used to generate electricity in wind power plants. During strong winds, storms and dams, centrifugal forces can damage the wind wheel blades, so the WED will be equipped with special devices to turn the blades at the same time, depending on the location of the blower. Their useful work coefficient (use of wind energy) is high enough: 0.3-0.46.

The speed of the engines does not exceed the wind speed, and the weight per unit power is not large. They are used for devices with a small torque where it is possible to start the rotation without loading the product, that is, in the salt path in general. This was done with the help of a special centrifugal clutch, which interrupts the transmission for idle operation and for the operation of the wind wheel with the next automatic connection when reaching a given speed.

The high speed of rotation, together with the centrifugal and electric generator, affects their operation.

When the wind changes direction, the head of the wind turbine is automatically aimed at the wind turbines. The wind speed is controlled in the range of 6-40 m / s.

The characteristics of some types of wind turbines are shown in Table 2.8.

The speed of the generator must be 4 times or more than the speed of the wind turbine rotor. This can be achieved by choosing the right type of generator or transmission. Alternating current generators are widely used because they are cheaper, easier, and can generate electricity at a much lower rotor speed.

Table 2.8

Characteristics of wind power units

Key indicators	Type of wind unit			
	AVEU-6-4M	AVE-16	AVE-18-30	AVE-25-100/250
The diameter of the wind wheel, m	6,6	12,0	18,0	25,0
The height of the support,m	9,0	12,0	18,0	25,0
Number of papas	2	3	3	3
The average annual wind speed in the regions is not less than m / s	5,0	5,0	5,0	5,0
Calculated wind speed at rated power, m / s	9,5	10,5	10,0	9G'14
Range of operating speeds, m / s	4,5-40	4,5-25,0	5,0-25,0	5,0-30
Rated power, kW	4	16	30	100/250
Payback period, year	3-4	4-5	4-6	4-6
Annual savings of fuel, t	4,4	16,3	28	84
Weight, kg	1210	3300/4400	5000	18000

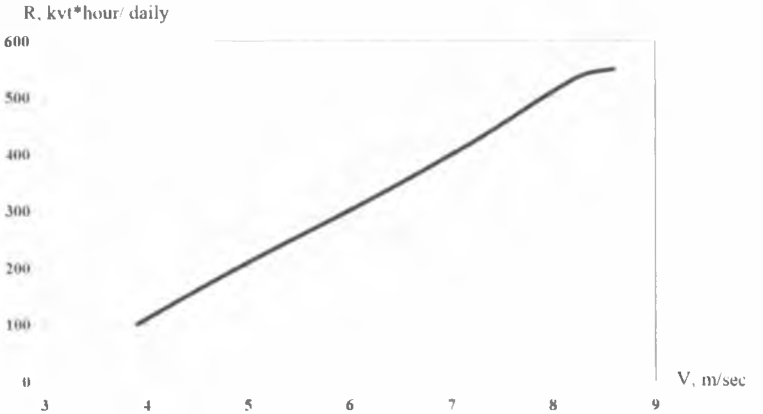


Figure 2.23. The dependence of electricity generation on wind speed. E - electricity generation; V - wind speed.

Figure 2.24. Roscoe Wind Farm, the largest wind farm in the world, is located in Texas, USA.

Currently, the world's largest wind farms are Roscoe Wind Farm in Texas with a capacity of 781.5 MW and Horse Hollow Wind Energy with a capacity of 735.5 MW. (Figure 2.24).

In 2010, construction began on an 800-megawatt Alta Wind Energy Center in California, USA.

Thanet Wind Farm offshore wind farm with a capacity of 300 MW, located in the North Sea in the county of Kent in the southeast of England, is the largest (Figure 2.25).

Figure 2.25. Thanet Wind Farm is the largest offshore wind park in the North Sea in Kent County, Southeast England.

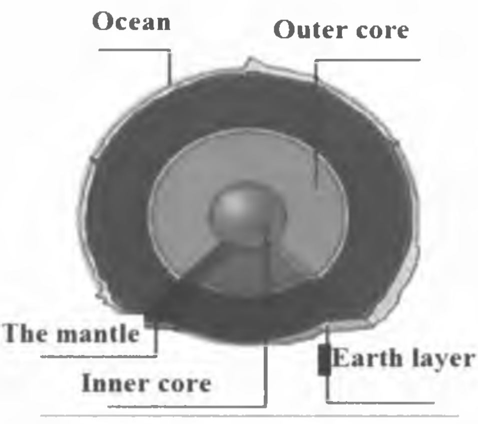
It is equipped with 100 wind turbines Vestas V90 with a capacity of 3 MW. The water depth there is 20-25 m. Price 1.4 billion. USD. Prior to that, Horns Rev 2 was an offshore wind farm with a capacity of 209.3 MW, located off the coast of the Danish peninsula of Jutland.

2.4. Geothermal energy

Geothermal energy (GTE) is the natural heat of the planet. All energy sources are divided into hydrothermal and petrothermal.

GTE is divided into aqueous, steam aqueous and steam types. Petrothermal energy is a source of water on Earth.

Water temperature or steam in all geothermal sources depends on the distance to the earth's mantle and its proximity to the magma. Thermal groundwater is found at a depth of 2-6 km above the ground when heated to energy temperatures (Figure 2.26).



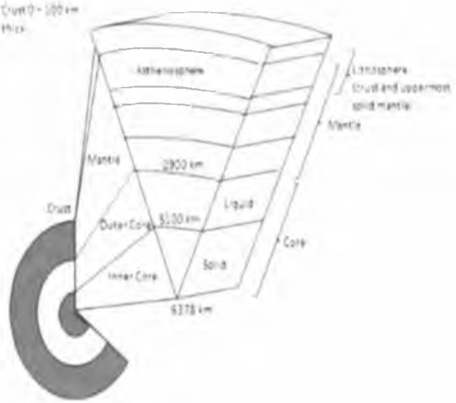


Figure 2.26. The structure of the internal structure of the earth.

Figure 2.27. Volcanoes near geothermal water.

• **The core of the Earth.** The central part of the earth at a temperature of 4000°C, and scientists believe that it is composed of molten iron.

• **Mantle.** The shell that surrounds the nucleus. Depth to the mantle can reach 2900 km.

• **Lithosphere.** It is called the earth's crust or upper solid layer (Greek "litos" - stone, "sphere" - sphere). Its thickness ranges from 30 km to 100 km under the continents, and 5-7 km under the oceans.

Depending on the size of the temperature can be divided into the following sources:

- weak thermal temperature up to 40°C;
- thermal temperature 40-60°C;
- high thermal temperature 60-100°C;
- overheating temperature above 100°C.

Aqueous geothermal springs occur at different depths. One of the conditions for their formation is a layer of impermeable rock, which transfers heat from the mantle to a large layer of water (Figure 2.27).

Water at a pressure higher than atmospheric pressure heats up to temperatures above 100 ° C and rises to the surface as a vapor-water mixture.

In steamaqueous and steamy areas, the water capacity layer is located between two impermeable layers.

The lower layer transfers heat from the mantle to the water, while the upper layer prevents it from escaping to the surface. In such places, water evaporates, and at high pressures it turns into very hot water. Vapors can be released to the surface by drilling. In this case, the steam itself comes to the surface from the well (Figure 2.28). This is called a case in point.

Geothermal energy devices (GTED) that use a mixture of high-temperature water or steam water. They are divided into the following types:

– hydrogeothermal devices, which use geothermal water directly from the ground;

– steam hydrogeothermal devices convert steam-water mixture heat into electricity or heat energy.

Figure 2.28. Geysers (h = 40-150 m)

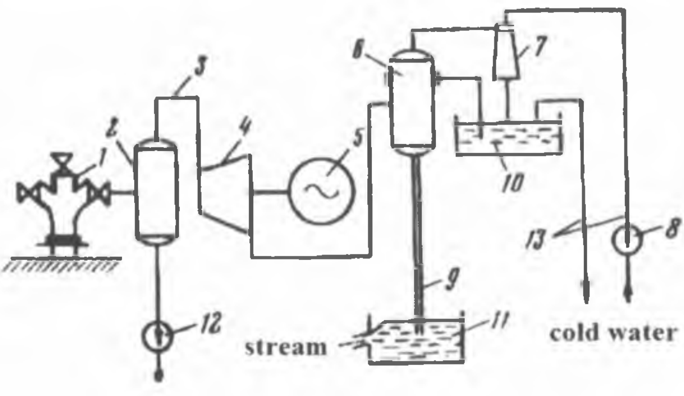
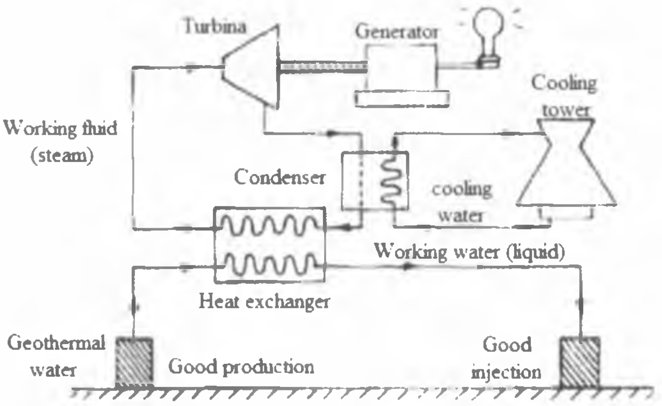


Figure 2.29. Technological scheme of GTED.

1- well; 2-separator; 3 -steam pipe; 4-turbine; 5-generator; 6-mixing capacitor; 7-water ejector; 8-ejector pump; 9-barometric tube; 10 - water cooling tank; 11 -drainage well; 12 - hot water pump; 13 - cold water pipeline.

The basis of GTED is as follows: several wells pump water to the required depth without digging underground. This water produces a mixture of steam and air from underground reservoirs. The hot mixture falls to the ground from the production wells and is used in heat turbines (Figure 2.29).

Used as well water - water from steam condensation can be used. This ensures that the environment is not damaged (Figure 2.30).



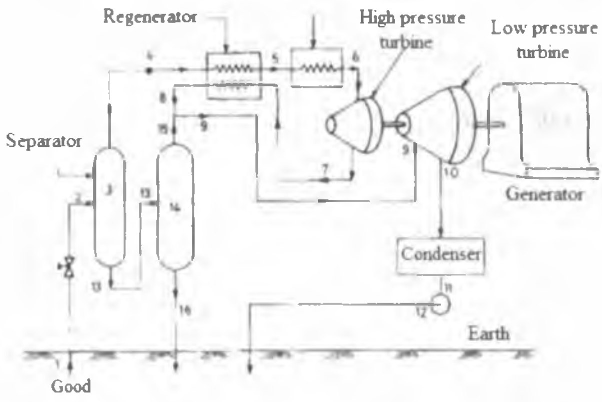


Figure 2.30. Scheme of hybrid geothermal devices.

GTED with a capacity of 2,000 MW is currently used in 12 countries around the world. Paujet GTED is used in Russia and Mutnov GTED is under construction.

Mutnov GTED requires 58 wells with a depth of 1500-2500 m to receive 200 MWh of power.

The largest geothermal power plant in the world is The Geysers Power Plant, a geothermal power plant with a total capacity of 1,517 MWh, consisting of 22 geothermal power plants in California (USA) (Figure 2.31).

Figure 2.31. The Geysers Power Plant is the world's largest geothermal power plant in California, USA.

It covers an area of 78 km^2 and meets 60% of California's northern coast's electricity demand.

The largest geothermal power plants are the Cerro Prieto Geothermal Power Station (720 MWh) in Mexico and the Hellishei Power Station (300 MWh) in Iceland (Figure 2.32).

Geothermal energy is used not only for electricity, but also for heating hot rooms and houses, hot water supply, irrigation of vegetables and fruits, greenhouse farming, drying, construction, treatment, extraction of valuable chemical elements from water and other areas.

The territory of Uzbekistan is also rich in thermal water resources.

The artesian basin around Tashkent has several water supply complexes and is located at a depth of 2-2.5 km, with a temperature of 75-80° C for weakly mineralized (up to 1 g / l) thermal waters with different mineralization and chemical composition. Thermal water reserves are estimated at more than 500 l / s.

Figure 2.32. Nes yavellir GTED in Iceland.

In Uzbekistan, thermal water is used for heating, in sanatoriums, and in greenhouses.

In the world experience, many regions rely on geothermal water for energy supply.

Iceland is solving its energy and heating problems through geothermal and hydropower.

In the Fergana artesian basin there are terminal waters of several water flow complexes, mineralization and chemical composition vary, water tennis reaches 70-90°C. These waters have a large flow and bass. Separate wells can produce geothermal water up to 30 l / s.

In the south of Uzbekistan (Syrdarya) geothermal waters occur at a temperature of 650°C, where the flow rate of some wells reaches 3000 m^3 / day. It is believed that these waters contain iodine and bromine. They can be used in combination for heat supply or for the production of valuable chemical elements.

Geothermal water heat can be used for electricity generation, residential and industrial buildings, heating and hot water supply, heating of greenhouses and greenhouses, etc.

High-temperature superheated heat carriers (steam-water mixture - heating temperature 2000°C and above) are used to generate geothermal electricity. Such a layer of water is found in Spain, Japan, the Kurel Islands, and so on.

Heating and hot water supply requires geothermal water with a temperature of 50-100°C, which is not available in Uzbekistan.

If the level of mineralization of geothermal water is up to 10 g / l, the harmful components in it can be used for hot water supply without exceeding the norm established for the pipeline. When the temperature of geothermal water is not less than 50°C, their use in hot water supply is carried out according to a very simple scheme. In a well, geothermal water is naturally placed in a payment tank (Figure 2.33). From the accumulator tank, this water is pumped to consumers through a pipeline. Heating water supply facilities are an efficient source of geothermal water.

With a flow rate of 1,500 m^3 / day, a well with a water temperature of 60-65°C can provide hot water to a residential area or 1,400 people in an urban-type pasture.

Geothermal water can also be used in hot water supply systems when the temperature is below 5°C, but it is necessary to heat the boilers with heat pumps (heating) before delivering them to the consumer.

In agriculture, there are great prospects for the use of geothermal energy, including the possibility of heating greenhouses (fruits, vegetables). For this purpose, a geothermal water temperature of 25 ... 100°C is sufficient.

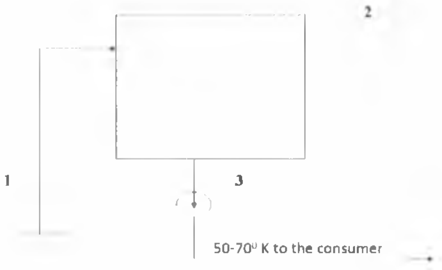


Figure 2.33. Scheme of continuous use of geothermal water.
1 -well; 2-tank accumulator; 3-hot water supply pump.

For this purpose, we can give the following example: to heat a greenhouse for 1 year, an average of 1600-1700 tons conditional fuel is required, however, one well is enough to heat 2 ha of greenhouses with a flow rate of 2000-2500 m^3 / day and 65-70°C geothermal water, which can produce 300-350 tons of fresh fruits and vegetables per year.

The economic potential of using natural heat is obvious for a protected soil.

There are also challenges to using geothermal water. This is because they are more or less mineralized and saturated with gas. These factors lead to the intensification of corrosion of metal bodies. The most aggressive geothermal water is a mixture of carbon dioxide and oxygen.

Attempts are made to reduce corrosion and eliminate aggressive gases and salts ($SaSO_3$, $SaSO_4$, etc.) against scrap formation, or by mixing anti-corrosion inhibitors and scraping reagents (sodium silicate, sodium phosphate hexomethane, etc.).

When used geothermal water is released into the environment, it creates an artificial pond. Additional purification of water-soluble substances may be required to meet the maximum permissible regulatory requirements. In such cases, additional measures are taken (water addition, re-treatment, etc.). Geologically used water from an ecologically clean point of view should be sent back to the aquifer at a distance of 1-2 km from the operating well. This ensures that the groundwater pressure and flow rate are constant.

2.5. Biomass energy

The main source of biological energy is biomass, which is produced and accumulated by nature.

Underlying this is the state of photosynthesis, in which solar energy is converted into chemical energy and stored in plants (Figure 2.34).

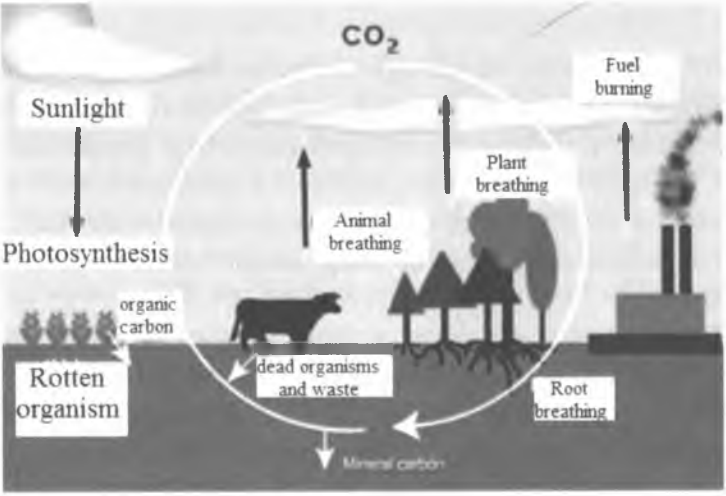


Figure 2.34. The process of biomass formation in nature.

The largest share of biomass is in forestry and agriculture. Forests produces 75 billion tons biomass per year, the energy equivalent of which is several times the annual global energy consumption.

In the 17th century, Jan Baptiste Van Gel discovered that the assembled biomass emits flammable gas.

In 1776, Alessandro Vol discovered the relationship between the amount of fermented biomass and the amount of gas released.

In 1808, Sir Humphrey Devi found methane gas in the biogas released from the fermented biomass.

The first documented biogas plant was built in 1859 in Bombay, India.

Used for street lighting in England in 1895.

In 1930, as a result of the development of microbiology, bacteria involved in the process of biogas production were identified.

The following 3 groups of bacteria are involved in the production of biogas:

- hydrolyzed bacteria;
- acid-forming bacteria;
- methane-producing bacteria.

Biogas is used in room lighting, internal combustion engines, food preparation and others.

Other sources of biomass are grasses and crops. Weeds grow 2,500 billion hectare on the ground. Some of these fast-growing species can serve as a source of energy. The most important agricultural crops may be sugar cane, cotton stalks and other agricultural and industrial wastes.

6 tons of straw can be obtained from 1 hectare of wheat field. 50 million tons of sugarcane a year stems and 60 tons of waste can be obtained.

These wastes can be used to produce a variety of fuels: synthetic oil and gas, biogas and alcohols.

Biological mass is also formed in the oceans and seas. Ocean plants contain large amounts of water (up to 9%) that are difficult to burn for heat.

Of great importance in the production of electricity are: livestock waste, municipal sewage waste, industrial waste.

The formation of biomass in different processes involves the production of energy from them on various technological bases.

The biomass produced in the notary state is used by incineration in various combustion devices and by hydrolysis to obtain alcohol, ferment and dry drive. It contains 50% carbon, 6% hydrogen and 44% oxygen. The heat transfer capacity of wood materials is 14-17 kJ / kg.

The world's timber reserves are estimated at 360 km^3, or equivalent to 175 billion tons conventional fuel.

Charcoal is obtained from wood by heating it without oxygen. It has some advantages: high heat transfer capacity (twice), ease of transport and so on. Disadvantages: heat loss during combustion, low useful work coefficient (10%), atmospheric pollution, etc.

Plant biomass is of great interest in methane and alcohol production. In the production of methyl alcohol, the biomass is converted to carbon dioxide and hydrogen at a temperature of 300°C and 1000 atm. synthesized under pressure.

Ethyl alcohol can be obtained by hydrolyzing large amounts of cellulose and can be used as a separate fuel for engines or by adding it to gasoline.

For this purpose, sugar cane is promising because it is a fast-growing agricultural product.

Adding 10-20% ethyl alcohol to gasoline improves emissions and vehicle emissions, reduces hydrocarbon content by 20-30% and carbon dioxide emissions by 18-35%.

Processing of agricultural organic waste is carried out in biogas plants. In such devices, anaerobic fermentation of oxygen-free biomass produces biogas and high-quality fertilizers. Biogas is a mixture of various gases, of which 65% is methane, about 30% is carbon dioxide and 1% is hydrogen, oxygen, nitrogen and carbon. Biogas heat transfer capacity is 20-26 MDg / m^3. The process of biogas production is shown in Figure 2.35 and its technological scheme is shown in Figure 2.36.

Biogas is used in room lighting, internal combustion engines, food preparation and more.

In Uzbekistan, biogas device (BGD) is not widespread, and some experimental devices are being tested.

In Russia, several types of BGD have been developed, the technical characteristics of which are given in the table.

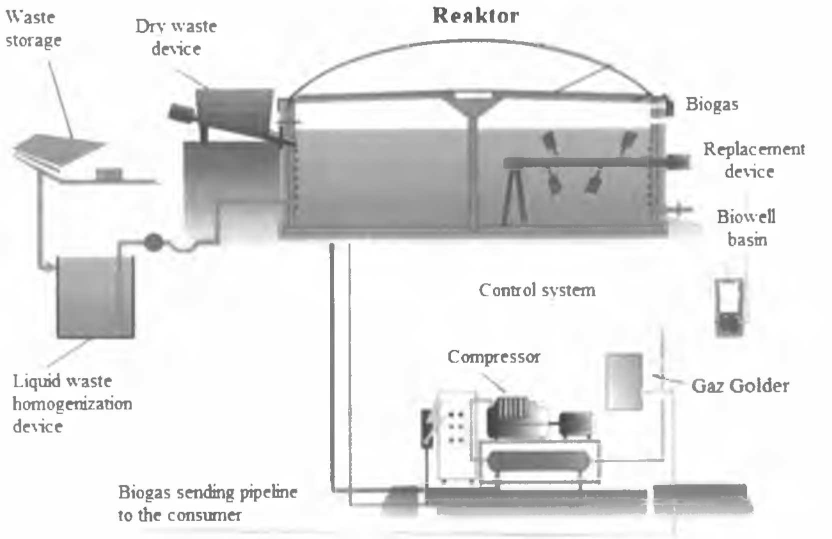


Figure 2.35. The process of biogas production.

Biogas production is used in China (7 million units), India (several hundred units), Switzerland, Germany, France, Italy, the Netherlands, the United States and many other cities. With a BGD capacity of 100-300 m^3, livestock farm waste is recycled.

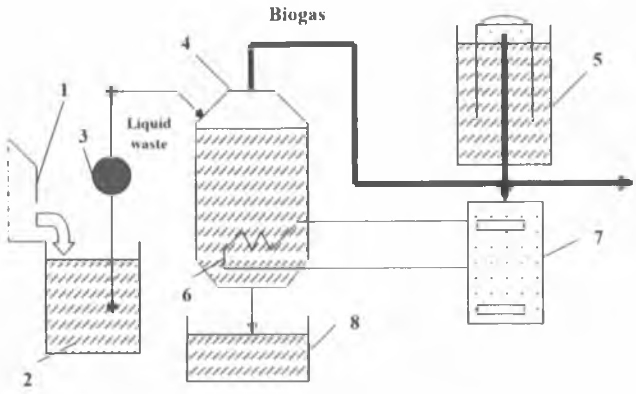


Figure 2.36. Technological scheme of biogas production.
1-farm; 2-waste receiver; 3-pump; 4-methane tank; 5-gas holder; 6- heat exchanger; 7- boiler; 8 - waste storage.

Figure 2.37. The world's largest Moon Alholmens Kraft (Jakobstad Power Station) biogas power plant in Pietarsaari, Finland.

The largest biomass burning power plant in the world is the Oy Alholmens Kraft (Jakobstad Power Station) biogas power plant in Pietarsaari, Finland (Figure 2.37).

Wood and peat are used as the main fuel, and coal can be used as an additional fuel.

The plant will generate 265 MWh of electricity, while the central heating system will receive 60 MWh of heat energy and 100 MWh of heat energy for the needs of the paper mill.

The station burns 1,000 m^3 of biofuel per hour.

The base of the fuel boiler is 8.5 m in diameter, 24 m in diameter at the top and 40 m high.

2.6. Hydropower. Small, micro and picoHPP

History and current state of development of small hydropower.

There has been a growing interest in renewable energy around the world since the 1970s. This was due to rising prices for oil and oil products. In addition to non-conventional solar, geothermal and wind energy, it also included conventional hydraulic energy of rivers.

The use of fuel and energy resources is limited not only by its value, but also by its impact on the environment and the extreme complexity of the ecological process.

The fact that hydropower resources are being developed through large hydropower plants shows that attention is also being paid to small hydropower.

The first small hydropower plants were built in the 19th century and were designed to supply electricity to individual enterprises and small settlements. The number of such hydropower plants is small. They were then squeezed out by small thermal power plants (ThPPs) because they could be placed anywhere.

The second phase of construction of Small HPP took 40-50 years. There are more than 1,000 of them in the CIS, the United States, Japan, France and other countries. After that, the focus on Small HPPs declined again, and in many countries, 100 or 1,000 Small HPPs were decommissioned. The main reason for this is the development of large-scale energy and the construction of large hydropower plants, thermal power plants, nuclear power plants and power transmission lines.

At the end of the third stage of the development of Small HPP, the construction of a qualitatively new stage began in 10 years.

Each new stage is characterized by a high level of technical and economic progress in the construction, design and operation of Small HPP.

For example, improved hydraulic turbines of the second stage, which were replaced by the first hydromechanical devices, are characterized by high efficiency even after the 50s.

However, Small HPPs equipped with advanced hydraulic units have several drawbacks, one of which is the high specific construction cost.

In the third stage, the success of automation and control systems will make it possible to fully automate Small HPP.

Currently, more than 300 Small HPP are operating in the Commonwealth of Independent States (CIS), 24 of which are in Uzbekistan. The design of these HPPs differs from each other by their technical level. The economic analysis of Small HPP shows that all of them are profitable.

In the CIS, a long-term program has been developed to justify the parameters of the construction of HPPs. The basis of this scientific and technical research is:

– technical re-equipment, reconstruction, modernization of all decommissioned HPPs;

– construction of new HPPs for individual electricity consumers and reduction of fuel consumption for diesel power plants;

– construction of Small HPP facilities in reservoirs and canals of water supply networks;

– application of new technical constructions for Small HPP, creation of hydropower complexes;

– reducing the cost of main and auxiliary equipment Small HPP, etc.;

– optimization and implementation of Small HPP work with HPP, BGD and others.

The world's population has reached 6 billion and is growing by 2-3% per year. The average per capita electricity consumption is 0.8 kW, and the national difference in energy consumption is very large: ~ 10 kW in the US, ~ 4 kWh in European countries, and -0..1 in Central Africa. kWh. National income in modern countries is 2-5% per year. In such cases, energy consumption per capita should increase by 4-8% per year. This is a difficult task to ensure.

If 2 kWh of energy consumption per person is required in high comfort conditions, 500 W of power per m2 of the globe can be obtained from a renewable energy source. Assuming an efficiency of 4% for energy conversion, 100 m2 will be required to produce 2 kWh of power. Assuming that the average population density in and around the city is 500 people per 1 km^2, we will need to get 1000 kWh of electricity per 1 km^2 to provide them with 2 kWh of energy. Thus, renewable energy sources (solar, wind, geothermal, wave, hydraulic, etc.) can serve to meet the needs of the population. The only thing that needs to be studied is the convenient design of the converters that convert them into electricity, the increase in cost and other factors.

Classification of small, mini, micro and picoHPP

To date, there is no common classification for Small HPPs adopted by the World Bank. Their classification can be given on the basis of various parameters. For example, in Latin America, in terms of nominal power: picoHPP - 5 kW; microHPP - 100 kWh each; mini-HPP - 100 ... 2000 kWh, small - 1000 - 10000 kWh (in most countries up to 30,000 kWh).

At the X Congress of the World Energy Commission in 1977, it was chosen to include up to 10,000 kWh of hydroelectric power plants in Istanbul in 1977. In most countries, Small HPPs have a capacity of up to 30 MWh.

CIS *Small HPP* classification by pressure:

- low pressure N <20 m;
- medium pressure N = 20 ... 75 m;
- is divided into large pressure N> 75 m species.

In addition, the hydraulic unit can have a maximum capacity of 10 MWh and a total rated capacity of 30 MWh. Attention is paid to the diameter of the turbine up to 3 m.

Small HPP classification according to the mode of operation:

- power grid;
- individual consumer;
- work in parallel with another energy source for a particular consumer;
- automated and other classifications.

Depending on the amount of water used, it can be divided into natural water and regulated water.

Consumers of electricity from Small HPP can be divided into the following groups according to their use:

- rural settlement with a population of 200 people - 100 kWh;
- bakery with a capacity of 25,000 tons per year - 250 kWh;
- 100,000 m3 / year board production plant - 500 kWh;
- plant for the production of reinforced concrete products, 100,000 m3 / year - 1000 kWh;
- 30,000 t / year of sugar production - 100 kWh;
- irrigated area of 4,000 pumping stations - 10,000 kWh.

In developing countries, micro-hydropower plants are being built as the cheapest and most convenient way to provide electricity to remote areas that are not connected to the national grid. Funding for the construction of micro-hydropower plants in China is provided by local governments, but also partially funded by the state. Construction design work will be carried out by individual districts, however, overall control (coordination) will be provided by the Department of the Ministry of Water Resources. China's achievements in building micro-hydropower plants are enormous. Of the 90,000 small hydropower plants, 60,000 are micro-hydropower plants. The equipment required for them is standardized and starts from 12 kWh (Figure 2.38).

In April 1990, at a workshop on small hydropower design in Edinburgh, Scotland, it was concluded that schemes of hydropower plants with a capacity of not less than 500 kWh were suitable for state construction. Small power (including microHPP) schemes are more suitable for private production.

Figure 2.38. MicroHPP located in Vietnam.

The attraction of private capital to small hydropower is seen in the countries of the Asia-Pacific region. In these countries, a large part of the population is deprived of electricity. For example, 76% of the population is in Indonesia, 50% in the Philippines and Western Malaysia, and 36% in Thailand. The Asian Development Bank has allocated $ 42 million for the construction of hydropower plants, but this amount is insufficient.

As for Russia, it should be noted that here, too, small hydropower is included in the list of local and regional facilities. According to them, the construction should be financed by the republics, autonomous districts, provinces, relevant enterprises, farms and individuals. MicroHPPs should be included in the number of objects subject to privatization.

Despite the stimulation of government documents, the development of micro-hydropower plants is at an early stage in both Russia and the CIS. Many publications have suggested that the reason for this is that the hydraulic equipment needed for micro-hydropower plants is not available in cash. Such statements are incorrect. In the CIS republics, there are a number of enterprises ready to produce equipment that meets the parameters of the type of water flow. But the demand for such a product here is not so great as in other countries.

The pace of development of micro-hydropower plants will not increase due to the low rate of privatization in the country today. There are thousands of neglected dams, mills and other hydraulic structures in the CIS. And here it is possible to install hydraulic power equipment at no extra cost. Only private businesses, and especially emerging farms, can improve the situation in these areas.

The economic performance of microHPPs depends on their installed capacity and the presence or absence of a ready-made front. As a result of static processing of 40 microHPPs with a capacity of 5 to 100 kWh, built in Nepal, Sri Lanka and Peru over the past two years, the following price distributions were made:

- construction part 28%;
- electrical part .... .30%;
- mechanical part 33%;
- etc. .... 9%.

For the optimal version of the equipment of MicroHPP, the relationship between these components is characterized by the following numbers:

- construction part 39.8%;
- electrical part 20.4%;
- mechanical part... .. ..39.8 / 6%.

It is a difficult issue for regions located far from the power system to offer a cheaper and more reliable energy source than picoGES. In Kyrgyzstan, for example, the 1.5 kWh Pico HPP has been operating for 3 years (18,000 hours) and generated 22,348 kWh of electricity. Electric receivers include a washing machine, a radio, a refrigerator, and an electric hob. The remaining part of the electricity was used to heat the rooms.

Parameters of microHPPs and their design schemes

Manufacturers are focusing on the production of micro-hydropower plants with a capacity of 100 kWh and less.

Experts from the Kyrgyz Energy Research Department were the first to create portable hydropower plants with a capacity of 0.25-3.0 kWh. In such a HPP, the water enters the turbine through a flexible pipe made of reclamation material (arm). Such pipelines are easily wrapped during transportation. Because of this method of water supply, such hydropower plants are called micro-hydropower plants. The use of the hand will limit the need to build dams and other stationary hydraulic structures.

The conversion of the mechanical energy of the water flow into the energy of the rotor rotation is carried out using a Bank turbine in a microHPP developed by KirNIOE (see Figure 2.9, d). In this turbine, the shaft is connected to the asynchronous generator shaft using a belt drive. The practical operation of such micro-hydropower plants has shown that they are highly reliable.

Later, the development of manual micro-hydropower plants was organized in Russia by PO LMZ (St. Petersburg), Sizran Heavy Machinery Plant, and in Ukraine at the Khar Kovturbina Plant (NPO "Turboatom").

Unlike the above-mentioned micro-hydropower plants, these plants use stationary jet turbines. These turbines are mounted on the same shaft as the generator (Figure 2.39).

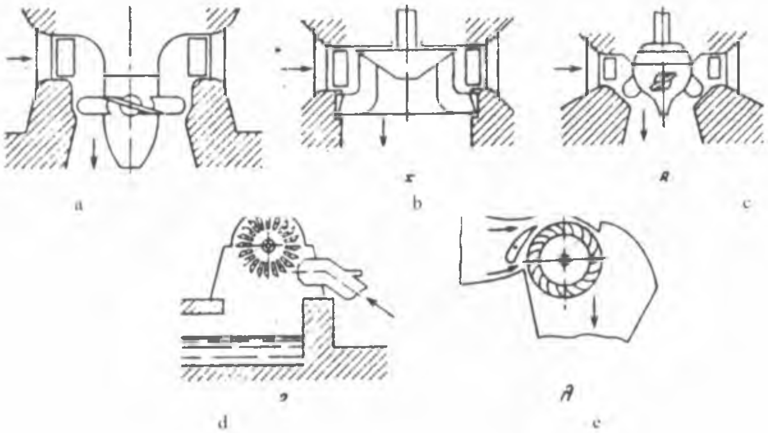


Figure 2.39. Types of turbine impellers:
a- axial; b-radial axis; c-diagonal; d-dipped;e-double bank impeller.

While POLMZ, NPO Turboatom microHPPs generate alternating current, a small SZTM AC device is designed to generate 12V DC. Due to the installation of a standard AC generator and a high-speed turbine, the microHPP developed at SZTM is lighter than the microHPP developed by Energozapchast for the same pressure and similar power. However, the use of voltage from such micro-hydropower plants has certain limitations in the national economy.

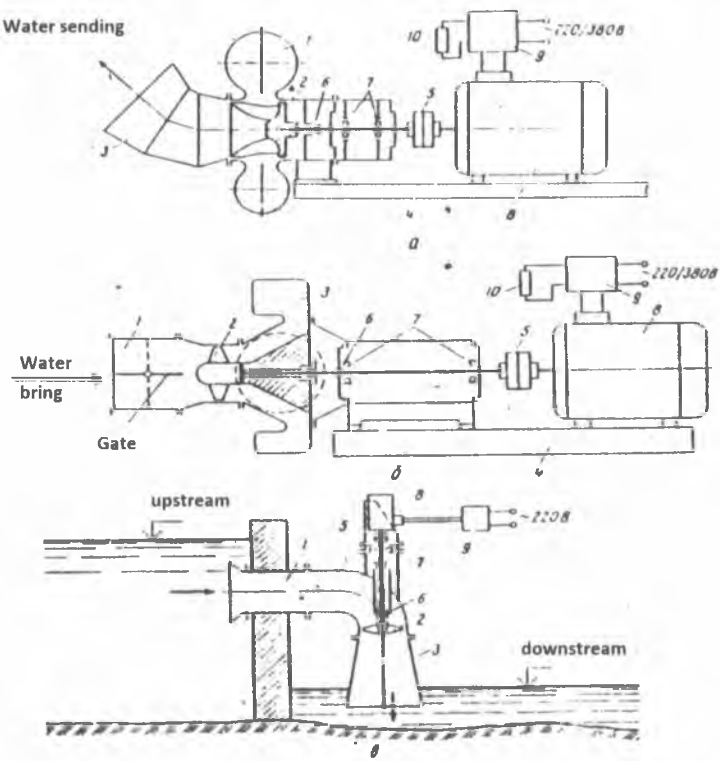


Figure 2.40. Construction scheme of microHPP developed by MP "Kebren":
a - micro HPP with a capacity of 30 kW at a pressure of 13 m;
b - microHPP with N = 4.5 m N = 6 kW; d is a portable microHPP with N = 1.2 m N = 1 kW; 1- water supply tract; 2 - working wheel; 3 - water driving tract; 4 - foundation slabs; 5-clutch; 6-box; 7- base bearings; 8-generator; 9 - management system.

Although it is necessary to create the pressure with the help of manual pipes for the micro-hydro turbines in question, they can also be used directly in hydraulic structures that generate pressure. It is important to note that this is the real way when it comes to creating a norm. In fact, even if the slope of the river is 0.1, a 50 m arm is needed to create a 5 m slope. However, such a slope is very rare, so the length of the arm should be increased to 75-100 m to create a 5 m slope. It is difficult to use the hand for this purpose to create a pressure of 10 m.

In micro-hydropower plants, manufacturers use fixed, axle, radial-axis and double-bank impellers.

Generators are made only on the basis of asynchronous motors and produce a voltage of three-phase 220/380 V.

The generator loading method is the main way to regulate the power of the hydraulic unit. Tubular electric heaters with air or water cooling system are used as additional ballast loading.

The design schemes of microHPPs are different. The absence of traditional designs is common today, as many private enterprises are engaged only in the production of micro-hydropower plants, and the experience of operating the developed equipment is relatively small.

Figure 2.40 shows a schematic diagram of a microHPP with a capacity of 30 kWh (the pressure is 13 m.). The turbine, generator 8 and ballast loading device 10 are mounted on a common foundation 4, and the foundation wall is mounted to the concrete base by 4 anchor bolts.

The turbine and generator shafts are connected via a repeating finger-bushing clutch 5.

2.7. Combined energy devices based on renewable energy sources

Today, in all developed and developing economies, in the context of declining global reserves of hydrocarbons, the development of practical use of alternative energy sources as a key factor in sustainable economic development and competitiveness is accelerating.

Uzbekistan has accumulated considerable experience in conducting scientific and experimental research in the use of alternative energy sources, primarily solar energy, which has been developed for several decades. The Republic has established a unique scientific and experimental center in Central Asia - the Scientific-Production

Association "Physics-Sun" of the Academy of Sciences, the results of which have been recognized worldwide. This is clearly stated in the Decree of the President of the Republic of Uzbekistan (March 1, 2013).

Research on the creation of low-potential devices for hot water and heat supply, photoelectric and thermodynamic converters for electricity, special materials synthesis technologies, the use of solar energy in the thermal treatment of materials and structures; experimental and design work is being carried out especially actively and efficiently.

The results of the research are being used experimentally on a large scale in various sectors and industries of the country's economy. For more than a decade, the country has been developing and experimenting with hot water supply systems for homes and social facilities on the basis of solar water heaters. In Tashkent, Samarkand region and other regions, solar water heaters have been installed. Production of photovoltaic devices of different capacities is mastered.

The conditions and opportunities created in Uzbekistan for the practical use of solar energy serve as a basis for the use of this region as a platform for the introduction of advanced technologies in this field not only in our country, but throughout Central Asia.

In order to make more efficient use of alternative energy sources, it is necessary to use them as a combination device, as well as the demand of consumers for electricity from renewable sources by the hour, day, week. It should be adjusted to take into account changes in the month, year and perennial period (Figures 2.44, 2.45, 2.46, 2.47, 2.48, 2.49). To do this, use RES-based devices:

- maximum electricity generation in parallel with the power system;
- underutilization of renewable energy;
- adapting the process of energy consumption to the process of energy production;
- combined use of several renewable devices and ensuring the regime of electricity consumption;

- ensuring maximum energy consumption during the maximum period of renewable energy sources and accumulation of surplus.

The most important issue is the timely supply of energy generated by renewable energy devices. Renewable energy sources depend on many factors, are unevenly distributed and depend on the nature of human activities and energy consumption.

Table 2.9

Technical and economic parameters of energy storage systems

Accumulation system types	Power range, MWh	Specific price, doll. / kWh
Hydraulic	0,5 -3500	400-1000
Aerial	5,0-150,0	500-1200
Inertial	0,5 - 60,0	400-700
Capable	0,01- 0,2	400-1500
Electromagnet	10,0 - 500	3000-100
Electrochemical	0,001-0,01	170-250
Hydrogen	0,001-0,1	450-1500

Accumulation is one of the main problems when analyzing the conversion of renewable energy from one type to another (Table 2.9). Mechanical, thermal and electrical accumulation methods and systems are used to solve this problem (Figure 2.41).

The table shows the power range and specific gravity for these storage systems. The compressed air storage is shown below.

At present, the United States, Germany and Japan allocate $ 150-200 million annually for hydrogen energy. The advantages of hydrogen as a fuel are encouraging researchers to find safer ways to burn and store it. In some countries, hydrogen-powered machines are being developed (Figure 2.42). The theoretical consumption of different fuels for 1 kWh of energy is given in Table 2.10.

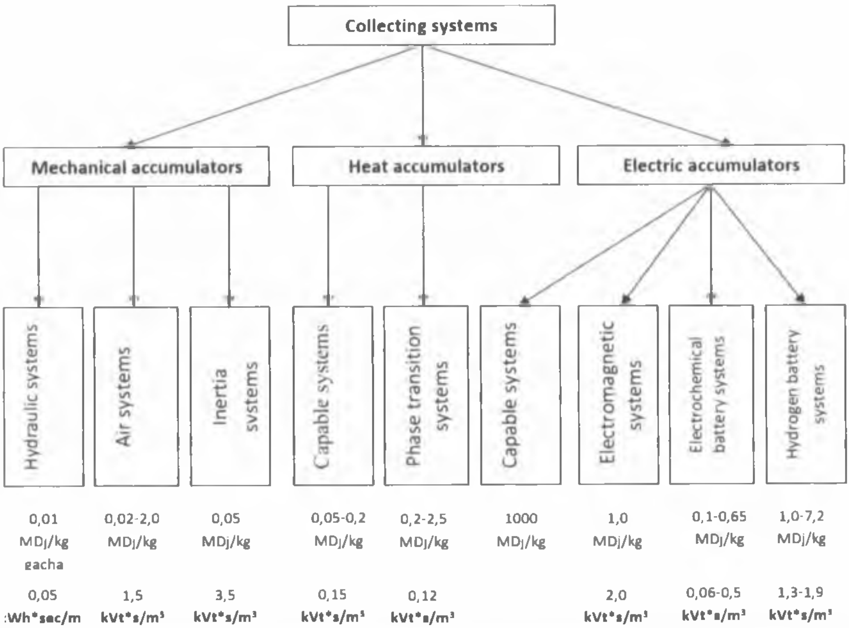


Figure 2.41. Energy storage systems.

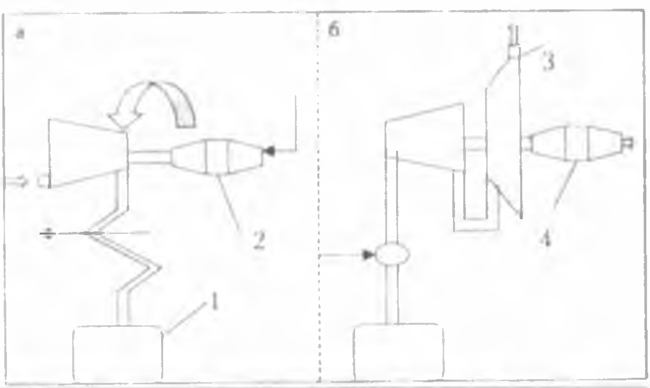


Figure 2.42. Air collecting gas turbine thermal power plant: operation in a-accumulation mode; b- operation in power generation mode. 1 - compressed air collection; 2 - electric motors; 3 - exhaust pipe; 4 - electric generator.

Table 2.10

Theoretical consumption of various fuels for 1kWh·hour energy

Fuel	Outlay, g/kWh-s
Hydrogen	29,8
Carbon	109,8
Methane	70,4
Carbon monoxide	392,8
Methanol	164,5
Propane	75,7
Gasoline	80

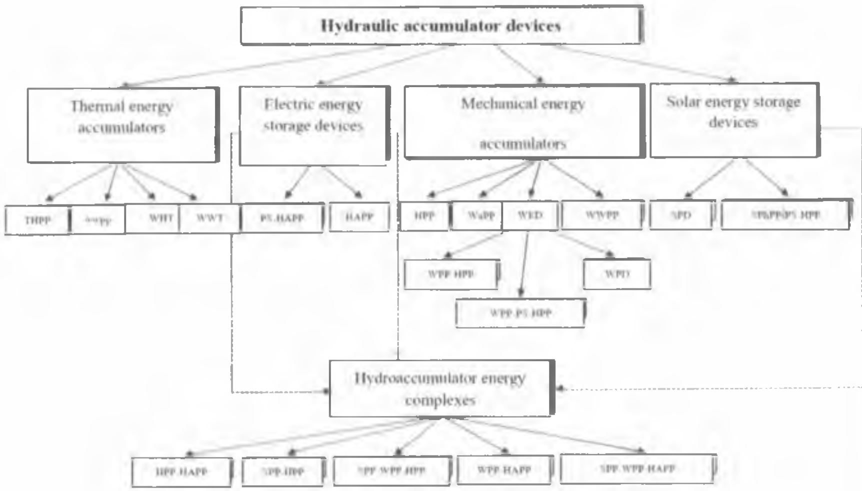


Figure 2.43. Classification of hydroaccumulator devices.

THPP-Thermal Power Plant, **WWPP**-Water Wind Power Plant, **WHT**- Wind Hydro Turbine, **WWT**-Water Wind Turbine, **PS HAPP**-Pump Station Hydro Accumulation Power Plant, **HAPP**-Hydro Accumulation Power Plant, **HPP**-Hydro Power Plant, **WaPP**-Wave Power Plant, **WED**- Wind Electrical Device, **WPP**-Wind Power Plant, **WPD**- Wind Power Device, **SPD**-Solar Pump Device, **SPhPP**- Solar Photovoltaic Power Plants, **SPP**- Solar Power Plants.

Combined power plants will have the opportunity to improve their technical and economic performance when they are at HPP, PS, HAPP and Hydroelectric Power Stations. In the process of hydraulic accumulation, electricity is converted into mechanical energy of water, and the reverse process is observed (Figure 2.43).

In the conversion of solar energy into hydraulic energy (solar pumps) or in the photoelectric conversion of solar energy, water is pumped to and used in the upper water basin. According to this process of energy conversion, the concept of hydraulic accumulation can be given in the form of a classification of hydraulic accumulators.

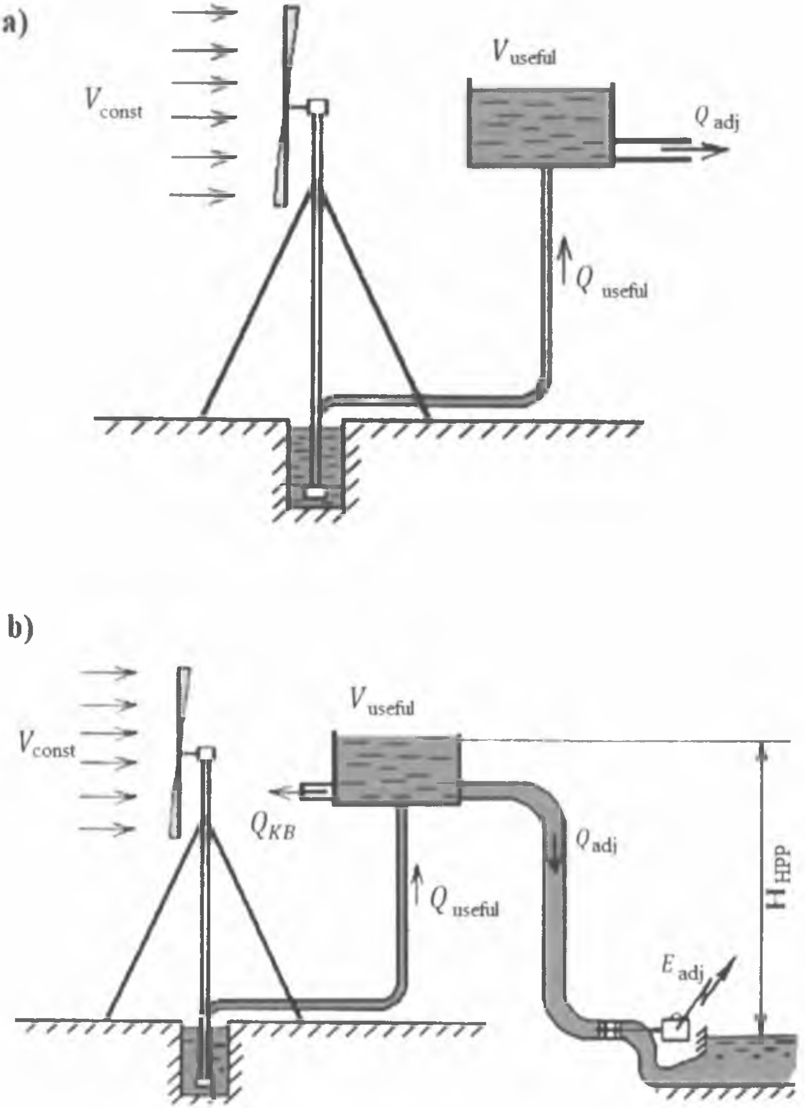


Figure 2.44. Various configuration solutions of hydroaccumulator devices.

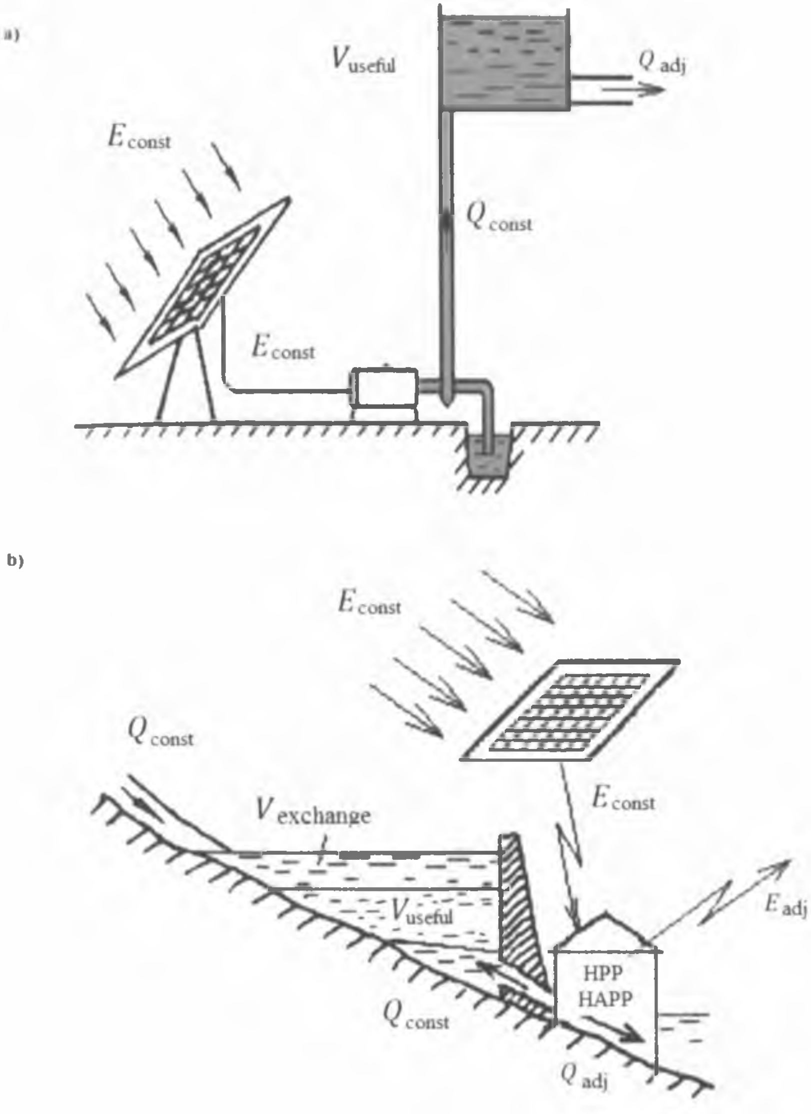


Figure 2.45. Combined operation of HPP-PS and HPP-HAPP.

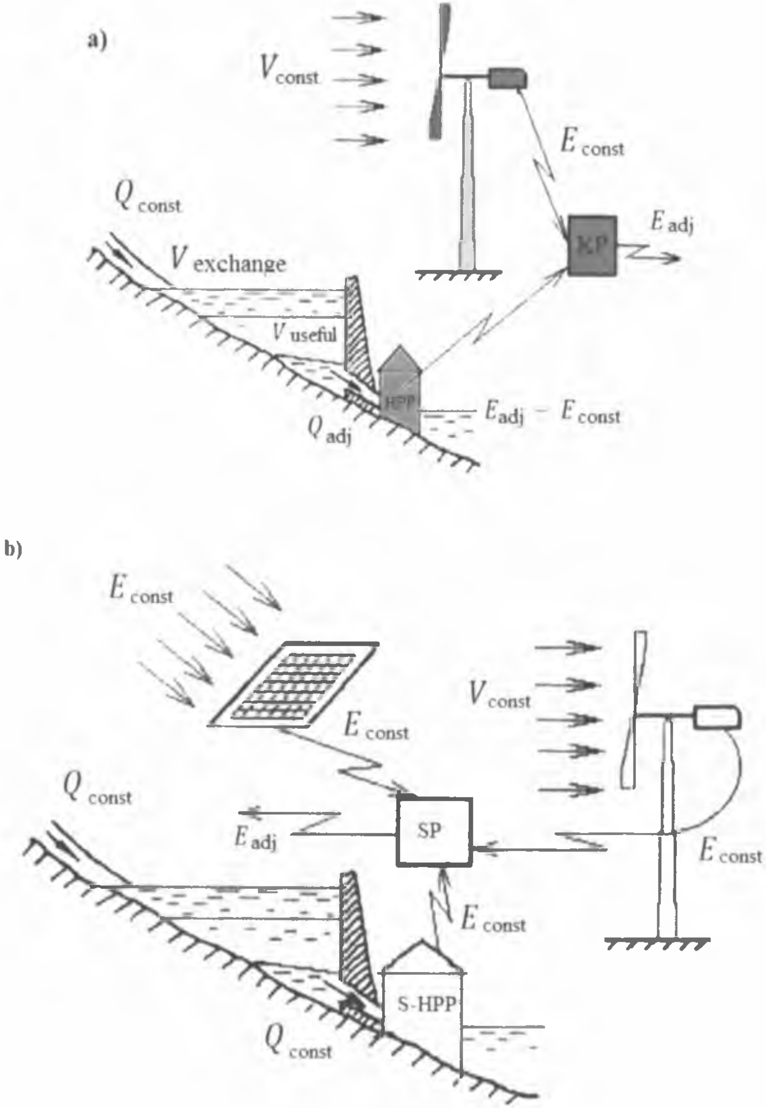


Figure 2.46. Combined schemes of 2 or 3 power plant devices.

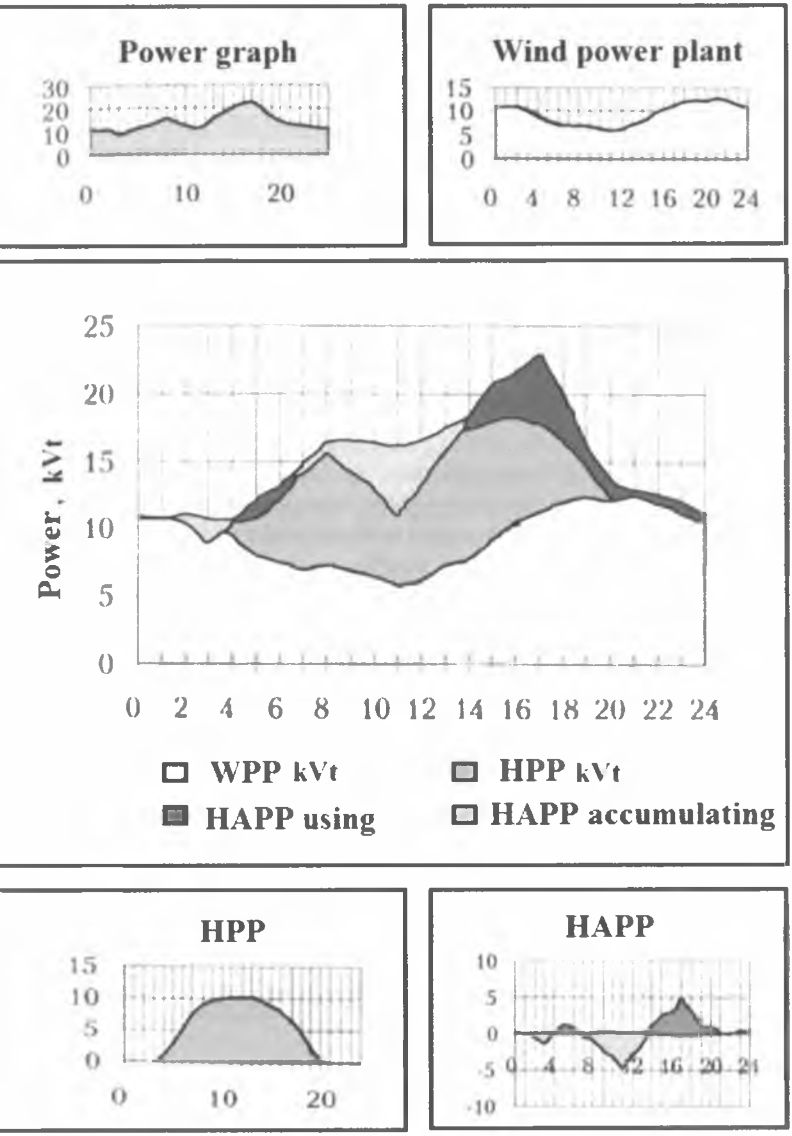


Figure 2.47. Download using wind electrical device and solar photo electrical device graphs covering the graph.

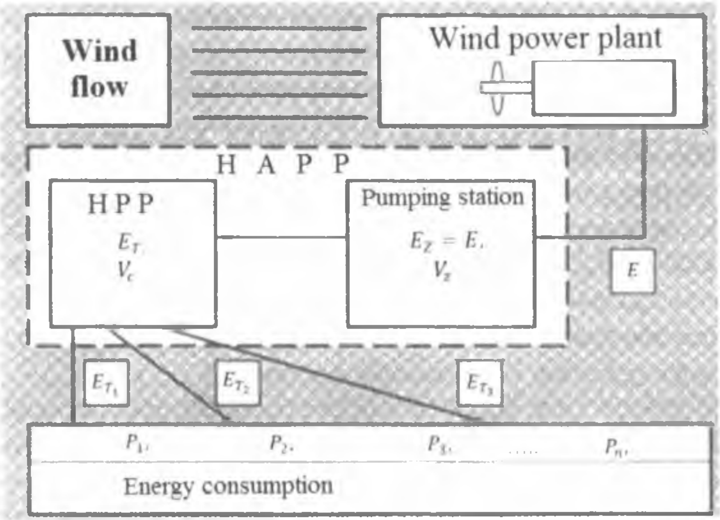


Figure 2.48. Electricity supply scheme used a combination of WPP-HAPP.

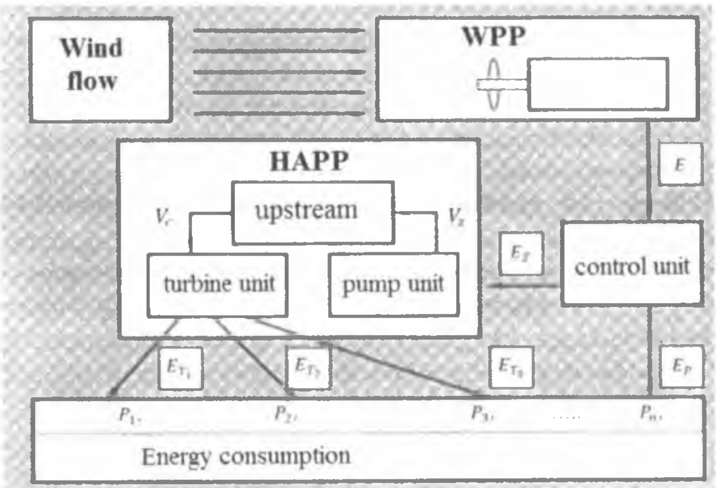


Figure 2.49. Parallel scheme of power supply for combined use of WPP-HAPP.

Control questions

1. Describe the types of non-renewable energy sources.

2. Describe the types of renewable energy sources.

3. What is the position of Uzbekistan in the world in terms of natural gas production?

4. Tell us about solar energy.

5. How many groups can RESs be conditionally divided into?

6. Tell us about geothermal energy.

7. What are the potential of renewable energy sources in Uzbekistan?

8. Tell us about wind energy.

9. What types of impellers are used in microHPPs?

10. How many groups of electricity consumers can be divided according to their use?

11. The following 3 groups of bacteria are involved in the production of biogas. Tell us about these groups.

12. Explain the operation of a biogas plant.

13. What are the types of small hydropower plants?

14. Explain the characteristics of wind power units.

15. Distinguish between non-renewable and renewable energy.

16. Describe the classification of hydraulic accumulators.

17. How many types of S-HPP classification are there in the CIS?

18. State the principle of operation of microHPPs developed by MP "Kebren".

CHAPTER III. POWER STATIONS AND POWER ENERGY SYSTEM

3.1. Classification of power plants

Power plants (PP) are a complex of equipment and devices, and their main function is to convert the used energy source into electricity (figure 3.1, 3.2, 3.3, 3.4, 3.5).

PP generates electricity and supplies power to industry, agriculture, utilities and transportation systems.

Some PP use different fuels as an energy source to generate heat at the same time and distribute the heat to businesses, residential and other buildings.

PP is distinguished by the following main qualities:

1. Depending on the type of energy source used: thermal (ThPP), fossil fuels, nuclear (NPP), hydropower (HPP), HPP, HAPP, PS, WWPP, non-conventional energy sources types.

Figure 3.1. View of a thermal power plant.

Figure 3.2. View of a nuclear power plant.

Figure 3.3. View of the hydroelectric power station.

Figure 3.4. View of a hydroaccumulation power plant.

2. Depending on the type of energy generated: ThPP, condensing PP, which provides only electricity; ThPP - thermal power plants (ThPP), which generate heat and electricity; the heat source is a product of used steam or combustion gases.

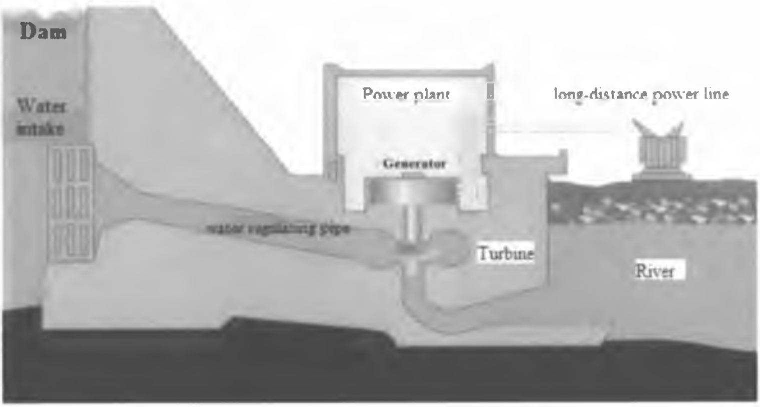


Figure 3.5. Diagram of a hydroelectric power plant that generates electricity through a hydro turbine at the expense of a water source.

3. Depending on the type of heat engine:

- steam turbine PP (TPP and NPP);
- gas turbine PP (GTEP);
- steam and gas turbine units (SAGTU);
- PP with internal combustion engine.

4. According to the purpose of use of PP: district PP (public use) which serves all types of consumers and is an independent manufacturing enterprise. and distributes electricity to rural areas.

For each PP, a technology will be developed to convert the primary energy source into electricity, and thermal developments will be created for the TPP.

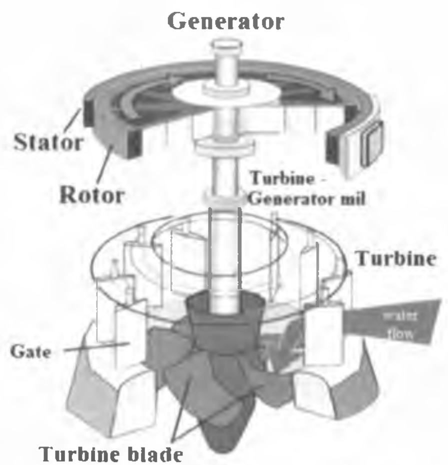


Figure 3.6. HPP aggregate scheme.

This technological process determines the sequence of the process of generating electricity and heat and provides it with the necessary main and auxiliary equipment (steam boiler, nuclear reactor, hydraulic turbine, steam and gas turbine, electric generators, etc.) The scheme provides for the process of mechanization and automation of electricity and heat generation.

Transmission of electricity to the power system is carried out through voltage transformers and large power transmission lines, and heat energy is carried out through mains.

Figure 3.7. Aggregates that convert water flow into electricity in hydropower plants.

Each PP has its own nominal parameters, which determine the duration of operation of the plant and individual elements (turbines, generators, hardware, protection and automation, etc. - Figures 3.6, 3.7). The individual elements are characterized by their respective parameters (voltage, current, frequency, power, etc.).

3.2. Thermal power plants

Condensing power plants (CPP)

CPP is a thermal steam turbine PP, in which heat is first converted into mechanical energy and then into electricity when burning fossil fuels. Figure 3.8 shows a schematic of a condensing power plant.

Figure 3.8. Scheme of a condensing power plant.

The schematic diagram of the solid fuel CPP is shown in Figure 3.9. The fuel entering the PP is pre-treated. Commonly used coal from TPP is ground, dried, and ground into a fine powder in a special crushing plant.

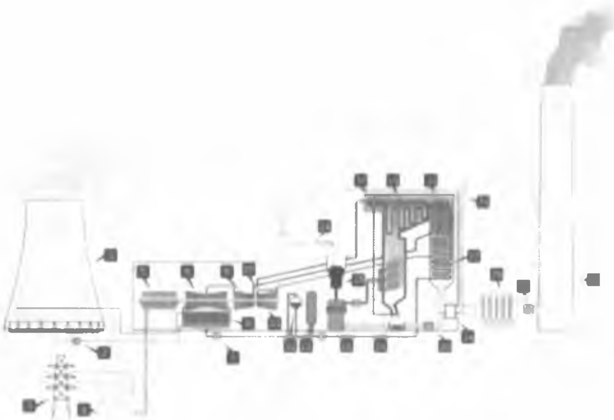


Figure 3.9. Technological scheme of condensing power plant.

A complex of devices for unloading, storing and primary cleaning of fuel is called a fuel farm or Fuel Transfer (FT). FT 1 and fine particle preparation 2 CPP form the fuel tract. The air from the coal particle is pumped to the boiler furnace 3 by a special pump. The fuel is passed through a special treatment plant 7, and the remaining gases are released into the atmosphere through the smoke extractor 6 through the smoke pipe 8. A set of 5-8 elements is called a gas air tract.

The heat generated by the combustion of the fuel is used to generate steam, which is superheated in a steam heater. The steam passes through pipe 9 to the Steam Turbine (ST). In ST, steam energy is converted into 10 mechanical energy and the generator produces 13 electricity. After the ST, the working steam has a final initial pressure of 13 ÷ 24 MPa, 0.0035…0.0043 MPa, and falls into a special condenser 11. In the condenser, the steam is converted into water (condensate) and it is pumped back to the boiler by 12 pumps. This cycle is called the vapor pathway.

To cool the steam, the condenser draws water from basin 17 using a circulating pump 14.

Water supply 17, circulating pumps 14, water supply 15 and transmission 16 pipes form the technical water supply system D.

CPP Useful Work Coefficient (UWC) is 32-35% for modern large blocks.

Thermal power plants

The Thermal Power Plant (TPP) is a type of power plant designed to provide heat and electricity to consumers.

The heat carriers are the steam from the turbines, which has a temperature of 100… 150°C.

The technological scheme of TPP differs from CPP by intermediate 'steam extraction' (Figure 3.10).

The steam coming out of the steam boiler enters the turbine 1 and it expands to the pressure in the condenser, then the potential energy is converted into mechanical energy and the generator produces 2 currents.

After a few steps, the steam from the turbine is sent to the consumer 3. Steam production and its parameters are determined by customer requirements.

Modern turbines can have several steam outlets. This steam comes to the network heating 5. The hot water supplied to the heat supply is circulated between the heater 5 and the consumer 4 via a mains pump 6.

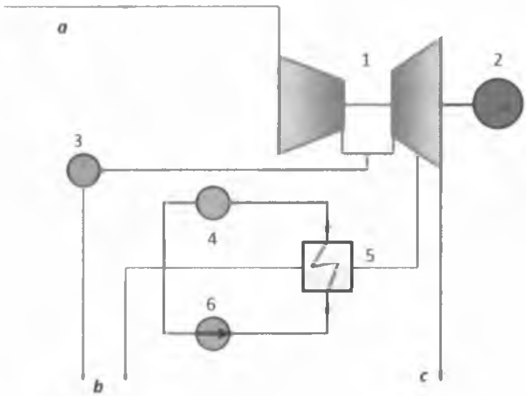


Figure 3.10. General scheme of the thermal power plant:
a - steam in the boiler; b - water supply tank; c – capacitor.

A system of pipelines that delivers hot water from the TPP to consumers and returns the used cold water to the CPP is called a heating network.

The CIS uses CPP power units with a critical steam parameter of 250 MW. It is planned to increase their capacity to 600 MW.

If the CPP has a steam extraction range, the UWC can be up to 60%, and the TPP UWC, which uses a steam turbine with reverse pressure, can be up to 75%.

Gas Turbine Devices (GTD)

The GTD consists of three main elements: an air compressor, a combustion chamber and a gas turbine.

GTD schematic diagram. Atmospheric air enters the compressor 1 and is compressed by 2 starter motors. It is then transferred to the combustion chamber 3 under high pressure (Figure 3.11).

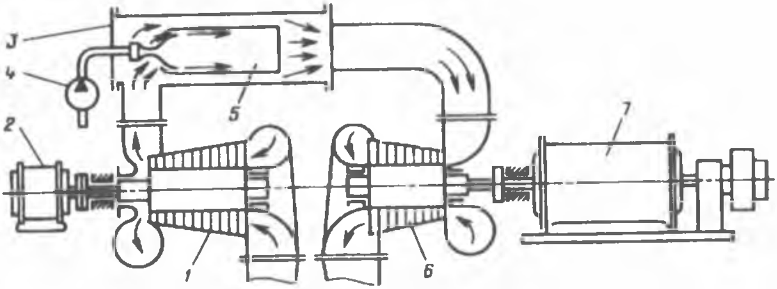


Figure 3.11. Scheme of a gas turbine device.

It is supplied with liquid and gaseous fuel at the same time by means of fuel pump 4. When air is supplied in an amount equal to the total combustion of the fuel, the temperature of the combustion products exceeds 2000°C. This is a high temperature due to the heat resistance of the turbine and other elements. Therefore, the amount of air is increased by 3.5… 4.5 and the temperature is lowered to 750-770°C. In the combustion chamber, the air is divided into two streams: the first is sent into the heat pipe 5 for complete combustion of the fuel, and the second is supplied from the outside of the pipe, which completely mixes with the combustion products and lowers the temperature. After the combustion chamber, the gases enter the gas turbine 6, which is located on the same shaft as the compressor and generator 7. There, the gas expands (to atmospheric pressure), rotates the turbine shaft, and is discharged through a flue.

GTD power is lower than that of a steam turbine and is 100-150 MW, and the UWC is up to 30%.

The advantages of GTD are the absence of a steam boiler, low demand for cooling water, high maneuverability, simplicity of automation, etc.

To increase the efficiency of the GTD, the compressed air in the compressor is heated in the regenerator before the combustion chamber, using the gas used in the turbine at a temperature of 400°C.

Steam gas appliances (SGA)

The SGA is a combination of a steam turbine unit and a gas turbine unit. In such cases, the heat used is combined with the heat from the gas turbine or steam boiler.

Again, the SGA design is cheaper, reducing its cost.

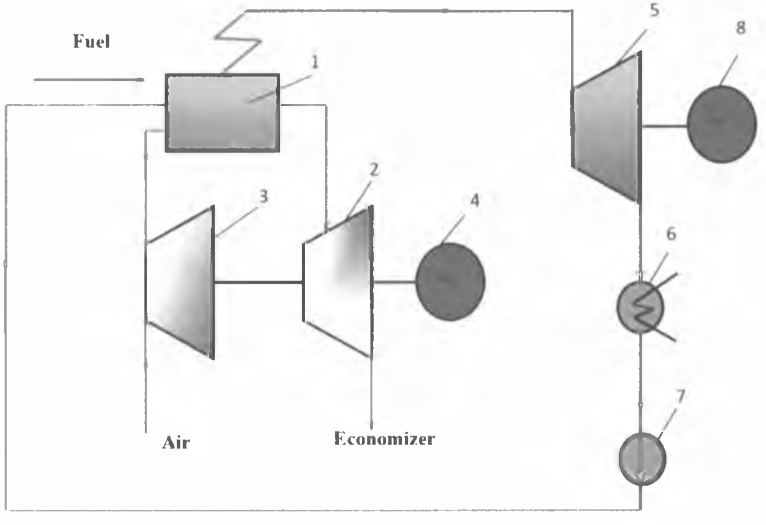


Figure 3.12. Schematic diagram of a steam gas appliance.

In Figure 3.12, a large pressure boiler is powered by 1 gas or refined liquid fuel. The flue gases leave the boiler at a high temperature and are fed to the gas turbine 2, with which a compressor 3 and a generator 4 are connected in one shaft. The compressor sucks air into the boiler combustion chamber. Steam from a large pressure boiler is fed to the condensing turbine 5, which is connected to a shaft generator 8. The steam from the used turbine passes to the condenser 6, which is condensed by the pump 7 and fed back to the boiler.

There are two types of SGA; there is a large pressure boiler and a type that discharges the used gas into the ordinary boiler combustion chamber.

Exhaust gases are transferred from the turbine to the economizer for boiler water.

Such structures UWC 42-43%. In another SGA scheme, the gas used is used to generate heat.

Discharge of used gas from the turbine to the combustion chamber in the Gas Turbine Devices (GTD) combustion chamber, the gas (fuel) burns at high air pressure and releases oxygen. Exhaust gases (16-18%) are sufficient to burn the bulk of the fuel.

Steam Turbine Device (STD) - steam turbine and gas turbine are formed in the power unit.

3.3. Nuclear power plants (NPP)

Today, nuclear energy is widely used in various economic sectors. Powerful underwater and surface canals are operated using a nuclear power plant. Mineral resources are being explored with the help of peaceful atoms. Nuclear energy is used in biology, agriculture, medicine, and space to establish radioactive isotopes (Figure 3.13).

The importance of nuclear power plants is difficult to assess in the energy balance of any country. NPPs are the third peak in modern world energy. The technical support of nuclear power plants is a great achievement of scientific and technological progress. Operation without a nuclear power plant has no impact on the environment.

Radioactive waste from nuclear power plants poses a threat to all living organisms. NPPs are very cost-effective compared to TPPs.

In 1990, the world's nuclear power plants accounted for 16% produces electricity. Such a power plant is produced in 31 countries and 6 are under construction.

The nuclear sectors of France, Belgium, Finland, Sweden, Bulgaria and Switzerland make up a significant portion of the energy sector, so the countries have sufficient natural energy resources. In these countries, 0.5…0.25% of the energy is supplied by nuclear power plants. In the United States, nuclear power plants generate 1/8 of the electricity, which is equivalent to 1/5 of the world's nuclear power.

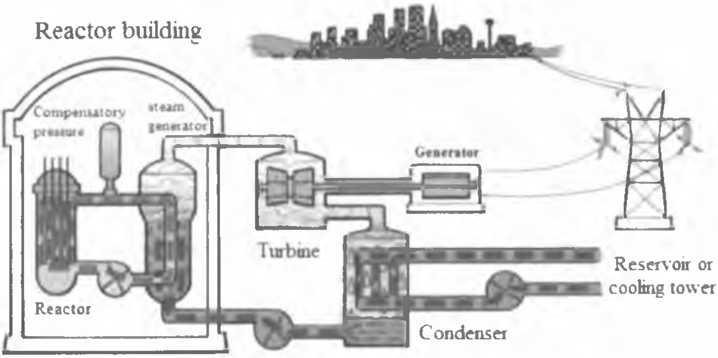


Figure 3.13. Simplified scheme of NPP.

In the development of nuclear energy, it is important to keep in mind that human health, any failure of a nuclear power plant can lead to catastrophic consequences.

During the operation of the NPP, more than 150 violations occurred in 14 countries at various rates. The most characteristic; 1957 Windskale (England), 1959 Santa Susanne (USA), 1964 Idaho (USA), 1979 Uch-Mile Island (USA), 1986 Chernobyl (Ukraine) NPP violations were observed.

Atomic energy is still a strong assumption. Proponents and opponents disagree on security, reliability, and economic statistics when evaluating NPPs.

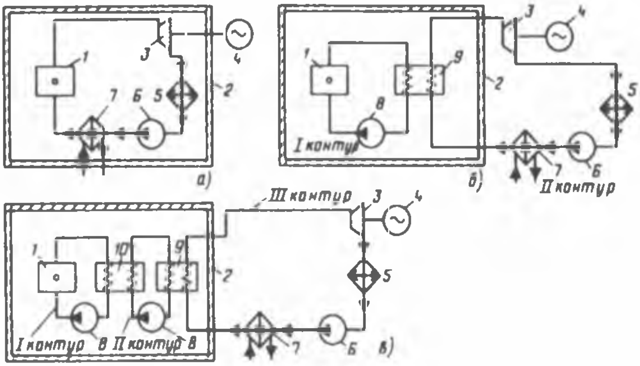


Figure 3.14. Schemes of single, double and triple circuit NPP reactors.

In the theory of relativity, A. Einstein states that m is a mass body and energy is converted into energy in the same way as energy:

$$E = m \cdot c^2$$

where s is the speed of light in vacuum.

According to this law, matter and energy are equivalent to each other, with a coefficient of proportionality c2, or in other words, if some mass is lost, the equivalent amount of energy is formed (or vice versa).

It is known that $c^2 = 9 \cdot 10^{20}$ cm / s, from which, according to Einstein's law, $c^2 = 9 \cdot 10^{20}$ erg or $9 \cdot 10^{13}$ Dj or $2.5 \cdot 10^7$ kW · s.

NPP reactors burn 1 kg of uranium per day at a heat capacity of 106 kW. It has electricity. In such a block u.w.c. At 33%, the heat capacity of the reactor is $3 \cdot 10^6$ kW, requiring 3 times more nuclear fuel, or 3 kg per day.

There are currently several types of NPP reactors. All reactors have an active zone (AZ) 1, which is filled with nuclear fuel. It is filled with a stopper (graphite or water).

AZ is coated with a reflector 2 to reduce neutron emissions. After the return, the concrete protection from the outside is placed against 5 radioactive radiation.

Replenishment of the reactor with nuclear fuel is especially critical. In order not to keep the reactor in critical condition during fuel combustion, strong neutron absorbers are introduced into the AZ from 4 times carbide. These rods are called regulators or compensators. Some of the rods are used to regulate reactor power (which is done automatically).

Depending on the type of heat carrier, the nuclear reactor and its use, NPPs are divided into one, two and three circuits. Their schematic is shown in Figure 3.14.

3.4. Electric power system

In power engineering (PE), the production process can be divided into three interrelated stages:

1) The process of generation (production) of PE, in which the main equipment is electric generators;

2) The process of modifying, transmitting and distributing EPs;

3) Consume PE. This process is carried out using transformers and the required voltage and current are delivered to consumers through overhead lines.

In this process, consumers place great demands on electricity - both in quantity and mode and quality (voltage, frequency) and uninterrupted power supply.

Modern PEs do not work separately, they work in a common mode to work together.

EPs, electricity and heat networks are interconnected, and the generalization of electricity and production, modification, distribution regimes is called energy system (ES).

The generalization of PE ES and grid electrical devices as well as power receivers, generation, transmission, distribution, and consumption is called power systems (PS).

The active power supplied to the consumers of the ES is called the load of the ES for personal needs, with the loss of power in the grid.

The load graph is called the P = f (t) bond.

The creation of PP is based on technical and economic conditions. Consolidating consumers into a single system, especially when consuming different types of electricity (industry, agriculture, transport, utilities, etc.), improves the use of the capacity allocated for each PP.

The total load schedule of the ES is relative to the individual consumer area, and when the total load decreases, the construction of a new PP reduces capital costs and reduces the cost of electricity generated.

Consolidation of consumers also reduces the relative variability of the total load in the PE, which is due to the mismatch between the loads of strong consumers (electric trains, electric ovens, etc.). This, in turn, makes it easier to keep the frequency and voltage of the ES operational.

It should be noted that the creation of the ES, in addition to economic indicators, ensures its reliability and stability of energy quality parameters without uninterrupted power supply. The total power and energy reserves will be reduced.

The technical and economic performance of the various ESs will continue to improve.

In this case, the greater the difference in the characteristics of individual ES, the greater the energy and economic efficiency when they are combined. Under these conditions, the weights of HPS and HNPP play an important role in the ES, as they serve to meet the demand for peak loading or the observed reduction in energy consumption at night.

The advantage of Steam Electric Turbines (SET) is very noticeable when they are operated in different geographical conditions, as the maximum load hours are not suitable and the ES reduces the overall load and there is no need for additional power; second, the maximum load hours vary in the ES, making it easier for large areas of power supply to change power (maneuverability) in individual systems.

As an object of production, ES has several features:

1.Simultaneous production, distribution and energy consumption are observed in the production of electricity, so the imbalance between them is observed in the operation of the whole system and causes great damage the national economy.

2.ES promotes the widespread use of automation in the production of all electricity. In practice, powerful TPP blocks and individual EPs (HPS, HNPP, etc.) can be fully automated, and ES mode control can also be automated.

This means the development and application of scientific control automation Dispatch Management.

3.In general, the ES can be used in all types of energy resources.

4.ES provides electricity to all sectors of agriculture and ensures its continuous development.

5.The ES will have a variety of sources of electricity.

6.The ES operates continuously, although some individual elements are temporarily out of order.

7.As with all sectors of the economy, energy consumption should not be taken into account when planning energy production. In addition to the volume of the product, the mode of energy consumption over time is considered.

ES has a significant impact on the biosphere in connection with energy consumers - industry, agriculture, transport. With the continuous increase in the capacity of ES, the scope of the global impact on the environment is equal to the power of geophysical, geological and space events.

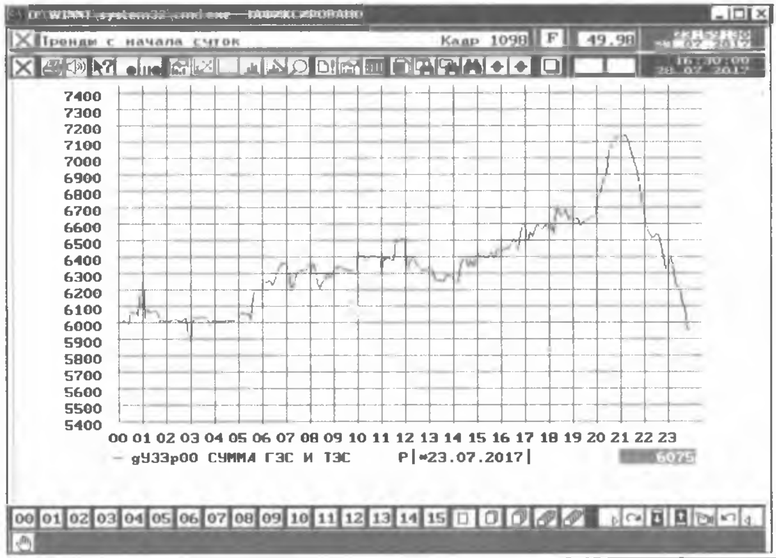


Figure 3.15. Power grid daily load schedule.

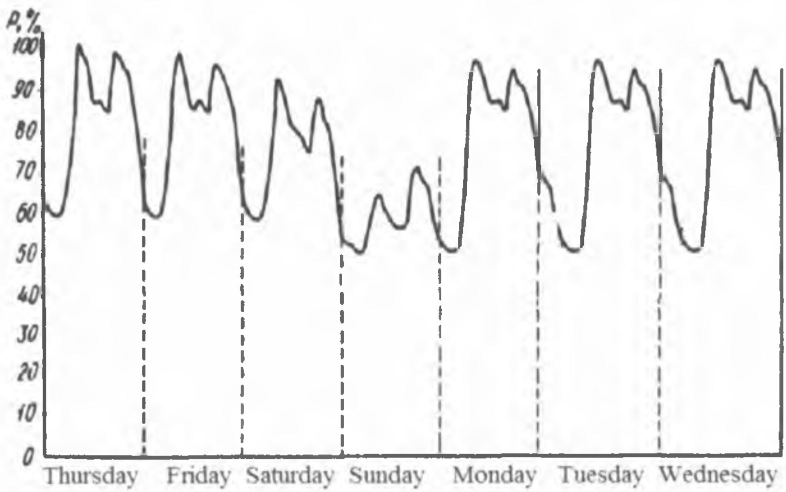


Figure 3.16. Power grid weekly load schedule.

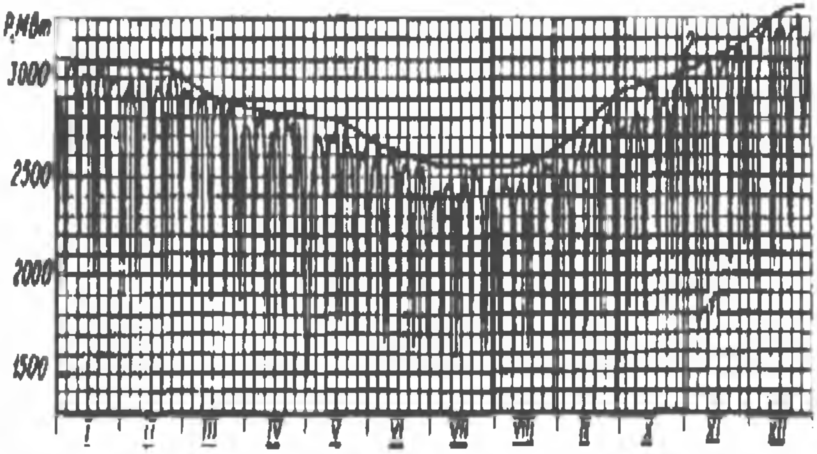


Figure 3.17. Power grid annual load schedule.

This requires a new direction in energy development planning in terms of energy sources and their location on the planet.

The ES load schedule is a characteristic of its main operating mode (Figure 3.15). The most commonly used ES operating and planning schedules are daily, weekly, and annual load schedules (Figure 3.16).

The appearance of the download schedule depends on the ES consumers, which have large downloads in the winter and small downloads in the summer. In some EU countries, pumping stations for summer irrigation in Central Asian countries may have higher summer loads than winter ones in terms of energy consumption (Figure 3.17).

The daily load schedule is mainly characterized by three indicators: maximum daily load P^{max}, minimum daily load P^{min} and the average daily load $\bar{P}_h = E_h / 24$.

Zone 1 of the graph is the base, from $\bar{P}_h$ to P^{max} – peak – 2 zone, lower from $\bar{P}_h$, zone which is higher than P^{min} is divided into 3rd zone.

Duration of use of the maximum load $h^{max} = E / P^{max}$.

E is the total energy consumed per day in the full EU.

Rated power consumption

$$h_r :$$

$$h_r = E / N_r = N_h \cdot 24 / N_r .$$

Efficiency from rated power

$$K_r = \bar{N}_h / N_r = E/(N_r \cdot 24) = h_r / 24.$$

Completeness, density coefficient of the load schedule

$$\delta = \bar{P}_h / P^{max} = E/(P^{max} \cdot 24) = h^{max} / 24.$$

The minimum coefficient is equal to the ratio of the minimum load to the maximum.

$$\beta = P^{min} / P^{max}.$$

The density coefficient of the load schedule depends on the composition of electricity consumers, production shifts, and so on. Typically $\delta = 0{,}5$ for the European ES, the city is 0.95-0.97 for utility consumers - Saturday and Sunday are larger.

The Central Asian Power Plant (CAPP), together with Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, has a 500 kW circulation system and 110 and 220 kV lines built in 1991. Uzbekistan is the main supplier of electricity to CAPP with 51%. 15% to the Republic of Tajikistan, 14% to the Kyrgyz Republic, 11% to the Republic of Turkmenistan and 9% to the Republic of Kazakhstan. The main CAPP dispatch center is located in Tashkent.

Control questions

1. What are the types of heat engine?
2. Describe the operation of a condensing power plant.

3. How many thermal power plants are there in Uzbekistan and what is their total capacity?

4. Describe the operation of the thermal power plant.

5. What are the characteristics of ES as a production facility?

6. Tell us about the role of hydropower in the power system.

7. Describe the operation of single, double and triple circuit NPP reactors.

8. What is the Useful Work Coefficient of the gas turbine?

9. What is the Useful Work Coefficient of your steamgas turbine?

10. Describe the working process of HNPP.

CHAPTER IV. WATER SYSTEMS AND THEIR STRUCTURES

4.1. WATER SOURCES

Water is one of the most important natural resources for human life. It provides functions such as food production, energy and industrial production, the satisfaction of human and sanitary needs.

Two-thirds of the human body is made up of water.

It is estimated that the weight of living organisms on earth is $2 \cdot 10^{11}$ t, of which an average of $1.4 \cdot 10^{11}$ t (70%) is water.

Water is the only natural resource that occurs in both liquid, solid and gaseous state.

In general, the planet has a lot of water resources, but most of them are unfit for human consumption.

Part of the earth's surface is oceans, seas, lakes and rivers, and the rest is land.

The total area of 69 major river basins is 47.3% of the land area.

97.2% of the world's water resources are concentrated in the oceans and cannot be consumed due to their high salinity. Freshwater from the glaciers that cover the land and mountains cover 2.2% of the world's water resources. These waters are difficult to use because they are far from human habitation.

All the rivers and lakes in the world, the total water resources of groundwater sources make up only 0.6% of the world's water resources. Only some of this water can be consumed by humans. Many of the groundwater in this reserve, as well as many lakes, are mineralized and cannot be used directly.

Groundwater accounts for 98% (37.5 million km^3) of the planet's freshwater resources, but about half of them are located at depths of more than 800 meters above the ground. It takes a lot of effort and money to get water up to this depth.

1.47% (125,000 km^3) of freshwater resources are concentrated in surface lakes and only 0.1% in rivers and streams. Mankind consumes only this water. As we can see, the reserves of potable water are very small, and they are declining every year due to human activities.

Freshwater resources are extremely limited. In contrast, the world's water consumption is growing from year to year.

In 2000, for example, the world consumed 26,540 billion liters of water per day, or 4,280 liters per capita, 72% of which was used to irrigate crops.

In most parts of the planet, there are about 2 billion people are suffering from a shortage of fresh water and another 2 billion about one person is facing a shortage of fresh water.

The world bank estimates that by the middle of the 21st century, 40% of the world's population will suffer from a lack of fresh water, and 20% of the population will have to live without fresh water.

In the assessment of water resources, the volume is divided into static water resources, measured in units of measurement (m^3, km^3), and renewable water resources, measured by the ratio of volume to time (m^3 / sec, m^3 / year, km^3 / year).

Each of them is important in nature.

Static water resources include seas, rivers, lakes, glaciers, and groundwater.

Renewable water resources are sources of water that are replenished by year-round water circulation between land and oceans.

The world's water cycle is 577,000 km^3 / year. Of this, 505,000 km^3 / year of water evaporates from the ocean surface and 72,000 km^3 / year from land (Table 4.1).

They return 458,000 km^3 / year to the ocean and 119,000 km^3 / year to land as rain, snow, hail and various precipitations.

Table 4.1

Water reserves in the hydrosphere

The founders of the hydrosphere	Water volume, thousand km^3	Of the total volume %
Hydrosphere Including:	1 454 703	100
Oceans	1 370 323,2	93,96
Groundwater	60 000	4,12
Of these, active water exchange zones	4000	0,27
Glaciers	24 000	1,65
Marine and reservoirs	280	0,019
Soil moisture	85	0,006
Vapors in the atmosphere	14	0,001
Flowing waters	1,2	0,0001

The main part of the water resources used in our country (about 80%) is formed in the mountainous areas of neighboring countries and flows into the territory of the country through the Amudarya and Syrdarya rivers and small rivers in their basins. The total water resources of the Amudarya and Syrdarya river basins are 114.4 km^3 per year with a 50% supply and 90.6 km^3 per year with a 90% supply.

11.47 km^3 of inland water resources are formed annually in the country, of which 4.82 km^3 is in the Amudarya and 6.65 km^3 in the Syrdarya basin.

In our country, agricultural land is the largest consumer of water in the economy, or 92% of the total water used is used for agricultural purposes. In addition, 5.5% of water resources are used in consumer services, 1.5% in industry, 0.8% in fisheries, and 0.2% in energy.

The width of water protection zones should be based on the function of reservoirs and other water bodies and the description of adjacent lands as follows:

– large reservoirs and other reservoirs - with a capacity of 1.1 to 10 km^3;

– average reservoirs and other reservoirs - with a capacity of 0.6 to 1 km^3;

– small reservoirs and other reservoirs - with a capacity of 0.2 to 0.5 km^3;

– very small reservoirs and reservoirs - with a capacity of less than 0.1 km^3.

Rivers can be grouped according to average annual water consumption as follows:

– large rivers - water consumption more than 100 m^3 / sec;

– average rivers - water consumption from 5 m^3 / sec to 100 m^3 / sec;

– small rivers - water consumption from 2 m^3 / sec to 5 m^3 / sec;

– very small rivers - water consumption up to 2 m^3 / sec.

The amount of hydropower potential of Central Asia shown in Table 4.2.

Table 4.2

The amount of hydropower potential of Central Asian countries

№	Republics	The amount of river water	Specific amount of water	Specific energy, thous.kWh·s 1 km^2	Energy potential			HPP amount.one	Total power, mln.kWh
					Theoretical	Technical	Economical		
					bln.kWh hours				
1.	Tajikistan	71	365	2100	299,6	143,6	85	82	32,5
2.	Kyrgyzstan	53	245	730	142,5	72,9	48	95	11,3
3.	Uzbekistan	117	27,3	200	88,5	27,4	11	76	3,4
4.	Turkmenistan	69	0,9	50	23,9	4,8	1,7	8	1,0
5.	Whole Kazakhstan	121	19,7	75	198,1	61,9	27	95	11,5
	including South Kazakhstan	-	-	-	66,2	20,6	9	23	4,1

The country has 30 HPPs with a capacity of 1,684 MW, which is 6.4 billion cubic meters per year kWh of electricity. At the same time, 30% of the hydropower potential of large rivers has been developed.

In addition to large rivers, the potential of small rivers, irrigation canals and reservoirs is estimated at 1,760 MW and generates 8 billion kWh of electricity per year.

The total hydropower potential in Uzbekistan is 7,445 MW, which produces 26.7 billion kWh of electricity per year, of which 1/4 is currently used.

Water resources are abundant in the CIS and around the world, but their distribution does not correspond to the students of the national economy for each region.

From a technical point of view, the redistribution of water resources is carried out using artificial reservoirs.

Calculate the amount of potential energy

Hydroelectric energy resource is determined by calculating the amount of potential energy or energy per unit time. Potential energy in large pools is a function of hydraulic energy coming from above or fluid flow consumption. When the pool is completely empty, the height of the pool will be h. The volume of water that passes through the surface of a living section per unit time.

Energy E, mass of liquid = m, drop height = h, free fall rate = g is equal to the product of:

$$E = mgh$$

Hydropower from the dam is generated by manually discharging water from the reservoir. In that case, energy is related to water mass consumption.

$$\frac{E}{t} = \frac{m}{t} gh$$

By swapping R with $^E/_t$ and $^m/_t$ with fluid velocity and we can replace it with current consumption:

$$P = \rho\varphi gh$$

or the approximate energy produced in a hydroelectric power plant is determined by the following formula

$$P = hrgk$$

where P is the energy in kilowatts, h is the height in meters, r is the flow of water per second in cubic meters, g is the free fall rate = 9.8 m / s^2, and k is the efficiency in 0 to 1. The efficiency of modern turbines depends on their size.

In some hydropower systems, water wheels can draw energy from the water mass without changing the water level. In that case, the allowable energy is the kinetic energy of the water moving in a straight line

$$P = \frac{1}{2}\rho\varphi\vartheta^2$$

here, ϑ – velocity of water,

$$\varphi = A\vartheta$$

there, A – permeable environment

$$P = \frac{1}{2}\rho A\vartheta^3$$

Water can receive both types of energy due to the rotation of the wheel.

The volume of global hydropower

According to the global share of renewable energy in 2008, hydropower accounted for more than 50% of all renewable energy sources. Figures 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7 show the world's largest hydropower plants.

The top ten largest hydropower producers in 2009 are shown in Table 4.3.

Table 4.3

The top ten largest hydropower producers in 2009

Country	Annual hydropower production (TWh-hours)	Built-in power (GVt)	Exact factor	Of total power Part
China	652,05	196,79	0,37	22,25
Canada	369,5	88.974		61.12
Brazil	363,8	69.080	0.56	85,56
USA	250,6	79.511	0.42	5.74
Russia	167,0	45.000	0.42	17,64
Norway	140,5	27.528	0.49	98,25
India	115,6	33,600	0.43	15,80
Venezuela	85,96	14.622	0.67	69,20
Japan	69,2	27.229	0,37	7.21
Sweden	65,5	16.209	0.46	44,34

Hydropower is estimated based on actual annual energy production or installed capacity. During the year, HPPs rarely operate at full capacity; the relationship between the annual average energy and the installed energy is the power factor. The installed capacity is the sum of the capacities of all generators.

The largest hydropower projects under construction around the world are shown in Table 4.4.

Figure 4.1. Image of the world's largest three-cave hydroelectric power plant.

Figure 4.2. Image of Itaypu HPP.

Figure 4.3. Image of Simon Bolivara or Guri HPP.

Figure 4.4. Image of Sayano-Shushensk HPP named after P.S.Neporozhny.

Figure 4.5. Image of Bratsk HPP.

Figure 4.6. Top - Ilimsk HPP image.

Figure 4.7. Image of Tukuruy HPP.

Table 4.4

Major projects under construction

Name	Max power	Country	Time of construction	The end of construct ion
Xiluodu Dam	12600MVt	China	December, 2005	2015
Xiang yeng, Project O'E	11000 MVt	India	April, 2009	2024
Dam TaSang	7110 MVt	Birma	March, 2007	2022
Dam Xiangnaba	6400 MVt	China	November, 2006	2015
Dam Nuozhadu	5850 MVt	China	2006	2017
Szinpin GES 2	4800 MVt	China	January, 2007	2014
Szinpin GES 1	3600 MVt	China	November, 2005	2014
Dam Pubugou	3300 MVt	China	March, 2004	2010
Dam Goupitan	3000 MVt	China	November, 2003	2011
Dam Guanyinyan	3000 MVt	China	2008	2015
Dam Lianghekou	3000 MVt	China	2009	2015
Dam Boguchan	3000 MVt	Russia	1980	2010
Chapeton	3000 MVt	Argentina		
Dagangshan	2600 MVt	China	August, 2008	2014
Dam Jinanqiao	2400 MVt	China	December 2006	2010
Dam Guandi	2400 MVt	China	November, 2005	2012
Dam Liyuan	2400 MVt	China	2008	
Dams and state Tocoma Bolivar	2160 MVt	Venezuela	2004	2014
Dam Ludila	2100 MVt	China	2007	2015
Dam Shuangjiangkou	2000 MVt	China	December, 2007	
Dam Ahai	2000 MVt	China	July, 2006	
Subansiri low Dam	2000 MVt	India	2005	2012

4.2. Water systems

Water resources in the water management system should be allocated first for drinking and sanitary purposes, then for agricultural production and environmental stabilization, and then for other needs.

The following positive developments have taken place in the world water system over the last 10-12 years:

The total demand for water is increased by 550 billion cubic meters;

– The impact of water shortages (less than 1,000 m3 / person) is estimated at 0.5 billion to 1.4 billion people;

The number of people suffering from hunger increased from 850 million to 1,020 million;

– 2 billion people are without access to sanitation;

– Damage caused by water-related disasters has increased 2.6 times. By 2050, 70% of the water received will be used for irrigation.

The available water resources in the Syrdarya and Amudarya basins and their distribution between countries are shown in Figure 4.8 and Table 4.5. Figure 4.9 shows the formation of water resources used within the territory of Uzbekistan.

Figure 4.8. Data on available water resources in the Syrdarya and Amudarya basins.

Table 4.5

Water resources in the Syrdarya and Amudarya basins and their distribution between states

Countries	Total	Including	
		Syrdarya	Amudarya
Uzbekistan	56,19	17,28	38,91
Kyrgyzstan	4,41	4,03	0,38
Kazakhstan	12,29	12,29	
Tajikistan	12,34	2,46	9,88
Turkmenistan	21,73		21,73
Afghanistan	7,44		7,44
Total	114,4	36,06	78,34

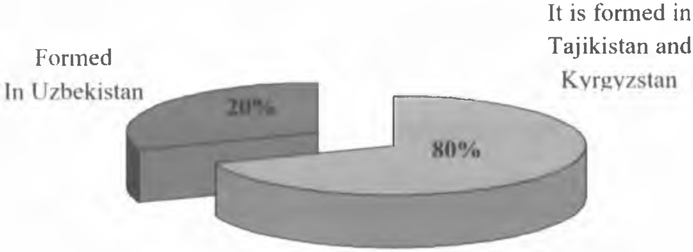


Figure 4.9. Formation of water resources used within the territory of Uzbekistan.

The use of transboundary watercourses between Central Asian states should be organized in accordance with the principles of international law and the Conventions, taking into account the interests of all states in the region.

The Republic of Uzbekistan is a party to the following universally recognized international conventions:

Convention on the Protection and Use of Transboundary Watercourses and International Lakes, Helsinki, 17 March, 1992

Convention on the Non-Shipping Use of International Watercourses, New York, 21 May, 1997

Basic principles of international conventions:

– the interests of all states are taken into account equally;

– fair and rational use of transboundary water resources;

– "not to harm" neighboring countries.

All major construction projects on transboundary rivers must be subject to international impartial environmental and technical expertise and agreed with neighboring countries.

Measures to increase water efficiency:

– improving the water resources management system;

– improving the technical condition of irrigation networks;

– improving the reclamation of irrigated lands and increasing their water supply;

– introduction of modern water-saving technologies;

– creation of an automated control and monitoring system;

– diversification of agricultural production.

In recent years, 1.5 thousand km of canals, 400 large hydraulic structures, 200 pumping stations, 386.0 thousand hectares of irrigated land have been reconstructed in the water system of Uzbekistan.

The main water management systems include:

– rivers - the amount of water collected from atmospheric precipitation - constant water currents moving along the slope of the earth's surface;

– canals - streams constructed with the help of artificial engineering structures designed to bring or deliver water to consumers;

– dams - hydraulic structures designed to artificially raise the natural water level of a river or canal several times and collect water;

– reservoirs are artificially constructed basins using hydraulic dams that contain a very large volume of water and occupy a large water area.

4.3. Rivers

A **river** is a constant stream of water that moves along the slope of the earth's surface as the amount of water collected from atmospheric precipitation.

The first part of the river is called the source and the last part is called its bottom. The head and end of a river are called its ***length*** (L). A ***river basin*** or ***water area*** (F) is an area that separates or covers water.

The difference between the ***heights of the beginning*** (H1) and the end (H2) of the river is called its ***dam.***

The slope of the river along its length is determined as follows:

$$i = \frac{H_1 - H_2}{L}.$$

A river valley is a part of a basin that descends and joins a river (Figure 4.10).

The tributary of a river is the part of the valley near the shore that is flooded during ***a flood*** (grasslands) (Figure 4.11).

The rivers are divided into straight and curved sections along their length. The ancient riverbed is divided into deep and shallow sections.

Coastal urethra is the line of the water surface that intersects the plane of the riverbed.

Urethra belongs to the left and right banks.

In rivers, the water level is H, the vertical height, from a predetermined horizontal plane to the water level. River flow is monitored and measured in special stands.

A river bed is a vertical plane that crosses a river.

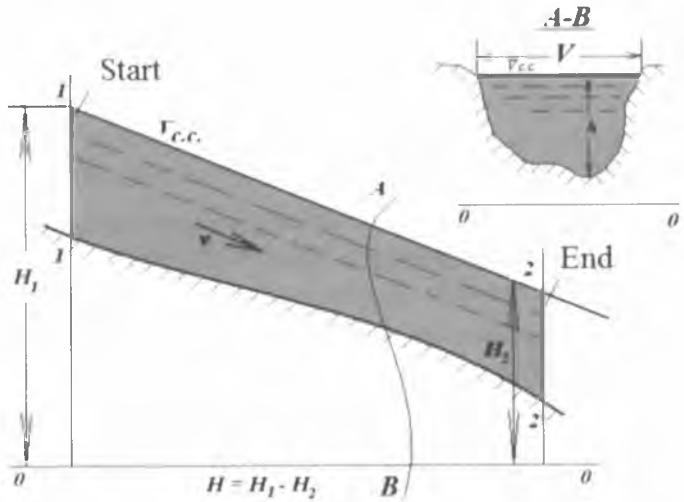


Figure 4.10. Drawing to explain the river.

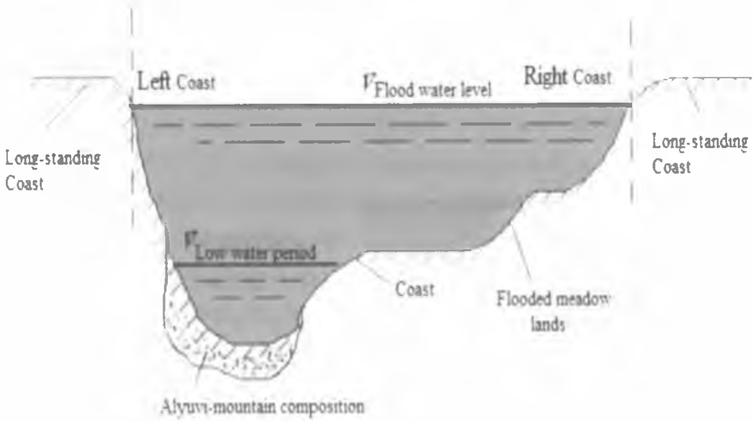


Figure 4.11. Elementary explanatory drawing of river cross-section.

River cross-section and morphometric characteristics

Based on the depth measurements, a cross-sectional profile of the river will be constructed. The construction work will be carried out as follows. A fixed point is drawn on the drawing and a horizontal line is drawn. This line corresponds to the plane of the water table, below which the measured depths are placed. The larger the vertical scale relative to the horizontal, the better the river relief. At the bottom of the profile is a table, which records the measured quantities. The table then records the basic morphometric characteristics (Figure 4.12).

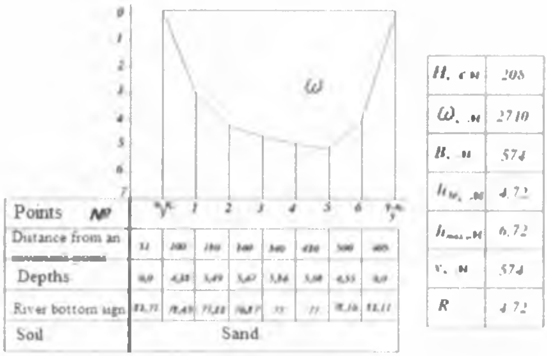


Figure 4.12. Construction of a river cross-section profile.

Morphometric characteristics of the river:

1. Water cutting surface - ω, m^2.
2. The width of the river - V, m.
3. The length of the wet perimeter - χ, m.
4. Maximum depth - h_{max}, m.
5. Average depth - $h_{o'rt} = \omega / V$;
6. Hydraulic radius - $R = \omega / \chi$.

The cross-sectional area can be determined using a planimeter or analytically.

Analytically, each measurement is obtained by summing the surfaces in the vertical range:

$$\omega = \frac{h_1}{2} b_0 + \frac{h_1 + h_2}{2} b_1 \ldots + \frac{h_{n-1} + h_n}{2} b_{n-1} + \frac{h_n}{2} b_n$$

Here's how to find a wet perimeter analytically:

$$X = \sqrt{b_0^2 + h_0^2} + \sqrt{a_1^2 + (h_2 - h_1)^2} + \ldots + \sqrt{a_{n-1}^2 + (h_n - hm_{n-1})^2} + \sqrt{b_n^2 + h_n^2}$$

For morphometric characteristics, graphs of water dependence can be plotted (Figure 4.13). If the river is strong, such graphs can be used for calculations. If the riverbed is deformed, these graphs will need to be corrected.

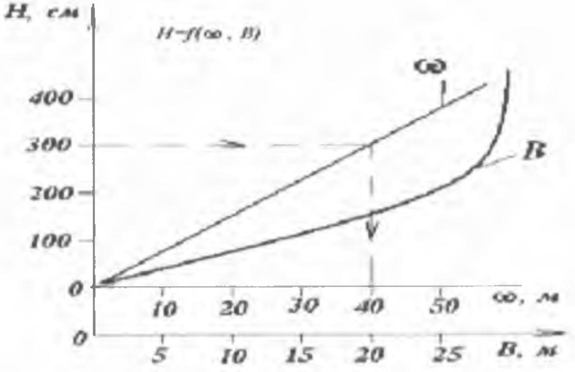


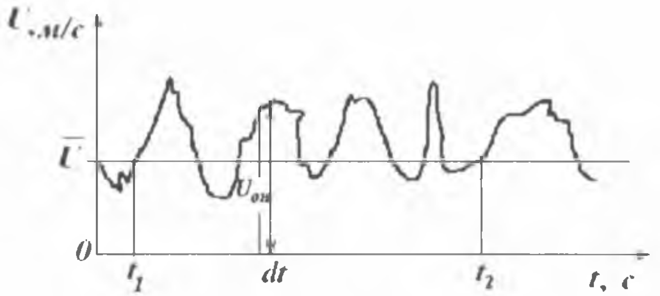
Figure 4.13. Morphometric characteristics water level dependence graph.

The distribution nature of river water velocity

River water is characterized by a decrease in the slope of the river under the influence of gravity. The larger the slope in length, the faster the water moves.

The nature of the velocity is greatly influenced by the roughness of the riverbed, and the velocity of the water at different points in the section is different.

Sand dunes at the bottom of the river, large rocks, and erosion-induced river changes create turbulent currents in the water, and these turbulent currents move throughout the stream. Such flows create a turbulent regime. In turbulent mode, the velocity field is very variable, complex in time, and velocity monetaryization occurs. As a result, hydrometry uses the concepts of instantaneous and mean local velocities (Figure 4.14).



Section 4.14. Graph of river water velocity distribution.

Instantaneous velocity is the velocity at a point where this velocity is observed in an instant. Hydrometry considers the instantaneous velocity vector, but also its components: longitudinal, transverse and vertical velocities.

The average local speed is given by:

$$U = \frac{1}{t_0}\int_{t_1}^{t_2} U_{onn} \cdot dt, \qquad t_0 = t_2 - t_1$$

there $\int_{t_1}^{t_2} U_{onn} \cdot dt$ – speed $(t_2 - t_1)$ surface area.

The distribution of velocity over water depth is governed by a certain law, which allows us to know the law, and in some cases to calculate the velocity using formulas without measuring it.

The velocity profile U, a figure formed by the vertical line and the plane of the water flow level, is called the ***depth velocity distribution diagram*** (Figure 4.15).

One of the mathematical formulas for the velocity diagram is the 1/7 law:

$$U = U_{max} \cdot \left(\frac{y}{h} \right)^{1/7}$$

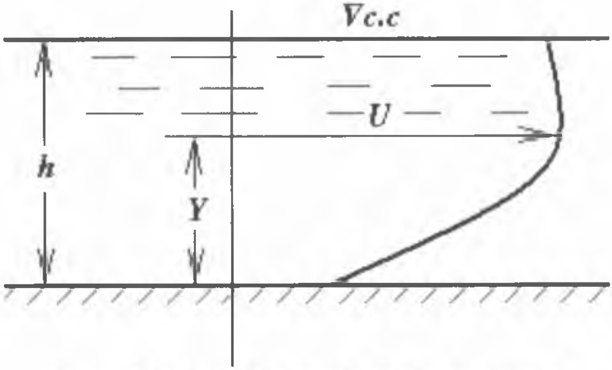


Figure 4.15. Speed by depth distribution diagram.

If we divide the surface of the velocity diagram by the surface of the water, we find the average velocity in the vertical:

$$\overline{U}_{\text{в}} = \frac{1}{h} \int_0^h U \cdot dh$$

For a well-distributed velocity diagram, the mean velocity is observed at a depth of 0.6 h in the vertical of the river flow (Figure 4.16).

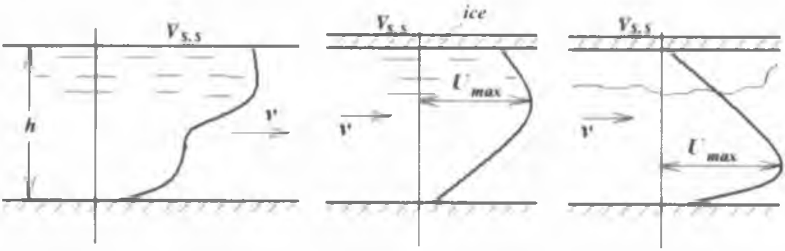


Figure 4.16. Average speed for river flow identification diagram.

The distribution of velocity across the river, across the entire movement, under the ice is shown in Figure 4.17 a), b), c).

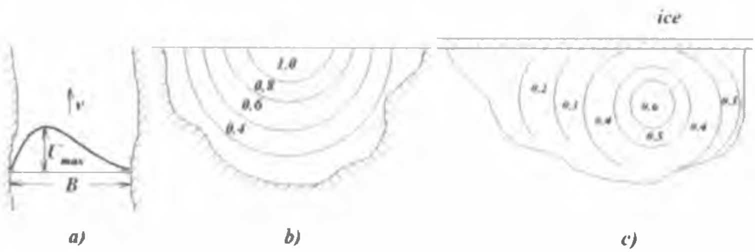


Figure 4.17. Velocity distribution across the river, under the entire movement of the ice:
a) speed velocity diagram across the river; b) open river isotopes;
c) isotope under ice.

4.4. Channels, their types and functions

The canal is said to be an artificial engineering structure designed to bring water to or from consumers.

Channels vary according to the following features:

- field of application;
- purpose;
- cross-sectional area;

- water permeability;
- type of coating;
- according to the flow, etc.

Depending on the area of application:

- irrigation;
- energy;
- forestry;
- transport;
- water sports;
- fishing, etc.

All channels will be for one purpose (to meet the needs of individual sectors of the economy) and multi-purpose (to meet the needs of two or more sectors). The first group includes the following canals: piped (communal industry and agricultural water supply), irrigation, drainage, energy, deforestation, navigation, fishing and canals. The second group includes, for example, transport - energy, fishing, water supply, etc.

Power lines are subdivided into those that deliver water to the HPD and those that carry water from its units. The HNPP channels are subdivided into those that connect the elevation, the high water basin, and the pressure basins, and those that connect the HNPP's low-lying buffer to the tuk basin.

The channels are divided into the following types according to the cross-sectional area (Figure 4.18):

- trapezoidal (a);
- right angle (b);
- round (c);
- parabolic (d);
- polygonal (e); [1]

The most commonly used type of channel is the trapezoidal channel.

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[1] Francesco Carrasco. Introduction to hydropower/ Published by: The English Press, Prakashdeep Bldg, Ansari Road, Darya Ganj, New Delhi, India, 2012

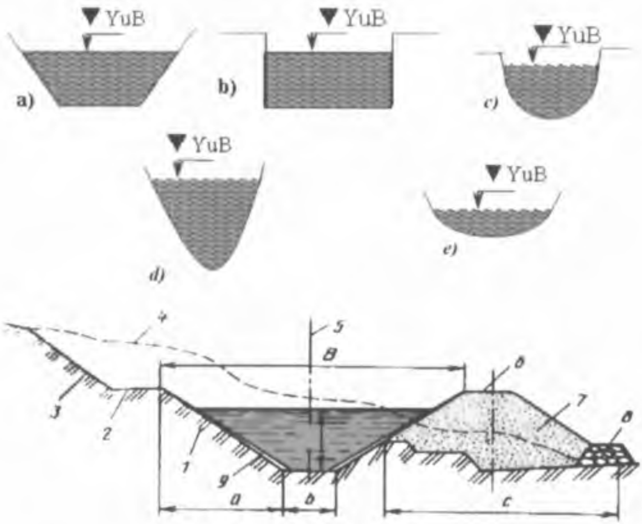

Figure 4.18. View of channels on cross-sectional area:
a) trapezoidal; b) right angle; c) round; d) parabolic; e) polygonal;
1 - underwater slope; 2 - berm; 3 - water top slope;
4 - natural ground surface; 5 - channel axis; 6 - top of the dam 7 - dam;
8 - drainage; 9 - coating.

Depending on the permeability:

- small - up to 5 m^3 / sec;
- small - from 5 m^3 / sec to 35 m^3 / sec;
- medium - from 35 m^3 / sec to 350 m^3 / sec;
- large - from 350 m^3 / sec to 800 m^3 / sec;
- very large - more than 800 m^3 / sec.

Depending on the type of coating:

- without coating;
- concrete (cement mixture);
- asphalt;
- asphalt - concrete;
- reinforced concrete;

– concrete slabs, etc..

Depending on the flow:

– ***self-flowing*** - the slope of the canal is different from zero (i> 0), ie due to the presence of the slope the water moves in the direction of the slope;

– ***machine*** - the slope of the channel is zero (i = 0), so the water in them moves by means of a pumping station.

Calculation of hydraulic elements of channels

Channels are built for the following purposes:

1. Irrigation.
2. Energy.
3. Water supply.
4. For water transport and other purposes.

Canals are built in different sizes, depending on the function and the amount of water taken from the river. Depending on the size of the channels V.S. Altunin channels divided into four classes (Table 4.6).

Table 4.6

Classes	Q, m^3/s	Channel type	Function	Period of use
IV class	<35	Small	Irrigation or water supply	Vegetation
III class	35-350	Medium-sized channel	Irrigation, water supply, water transport	Vegetation
II class	350-800	Large channels	Irrigation and water supply, water transport, energy	Throughout the year
I class	>800	Very large	Irrigation and water supply, water transport, energy	Throughout the year

To study the hydraulic element of the channel, consider a trapezoidal channel (Figure 4.19).

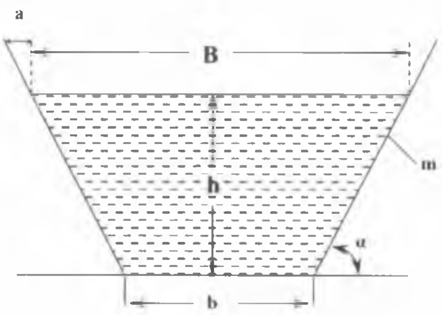

Figure 4.19. View of a trapezoidal channel.
B is the width of the canal along the water surface; b is the width of the channel along the bottom of the channel; h is the depth of the channel; m is the slope of the channel; a is the slope angle of the channel; a- slope size.

The cross-sectional area of the channel is determined as follows:

$$\omega = (b + m \cdot h) \cdot h \text{, m}^2. \tag{4.1}$$

The wetting perimeter of the channel is determined by the following formula:

$$\chi = b + 2 \cdot h \cdot \sqrt{1 + m^2} = b + m' h \text{, m.} \tag{4.2}$$

$$m' = 2 \cdot \sqrt{1 + m^2} \text{, m.}$$

The hydraulic radius of the channel is:

$$R = \frac{\omega}{\chi} \text{, m.} \tag{4.3}$$

The slope size a can be determined by the following formula:

$$a = h \cdot ctg\alpha \text{, m.} \tag{4.4}$$

The slope coefficient of the channel is found as follows:

$$m = \frac{a}{h} = ctg\alpha \,. \quad (4.5)$$

The values of the slope coefficient for different materials are given in Table 4.7.

Table 4.7

Creating a canal materials	*M*	
	Underwater	**On the water**
Dusty sands	3,0 ... 3,5	2,5
Sandy soil	1,5 ... 2,0	1,5
Small, medium and large sands	2,0 ... 2,5	2,0
Dense sands	1,5 ... 2,0	1,5

M = 1.5 if the canal surface is covered with rock piles.
The upper slope of the water is separated from the submerged slope by a berm: its width is not less than 1.5 m. The width of the channel depends on the bottom of the channel:

$$\beta = \frac{b}{h} \quad (4.6)$$

The wet perimeter of the channel can be written as follows:

$$\chi = h \cdot (\beta + m'), \text{ m.} \quad (4.7)$$

If we differentiate the formula (4.4.7), it looks like this:

$$d\chi = h \cdot d\beta + (\beta + m')dh = 0 \quad (4.8).$$

Follows

$$d\beta = -\frac{\beta + m'}{h} dh \quad (4.9)$$

We write the cross-sectional area of the channel as follows:

$$\omega = \beta \cdot h^2 + mh^2 = (\beta + m)h^2 = const. \quad (4.10)$$

Differentiating (4.10) we obtain:

$$d\omega = h^2 \cdot d\beta + 2(\beta + m)h \cdot dh = 0 \quad (4.11)$$

Instead of $d\beta$ in (4.11) equation we put $d\beta$ in (9) equation and we get:

$$\beta_{g.n} = m' - 2m = 2\left(\sqrt{1+m^2} - m\right) \quad (4.12).$$

To create the most useful hydraulic trapezoidal shape, choose a shape of the trapezoid in which the width of the channel depends on the bottom of the channel, should be equal to $\beta_{g.n}$.

We determine the water velocity in the canal as follows:

$$V = C\sqrt{R \cdot i}\text{, m/sec.} \quad (4.13)$$

Here, S is the Shezi coefficient, which is equal to:

$$C = \frac{1}{h} \cdot R^{1/6} \quad (4.14)$$

i – slope.

$$i = \frac{\Delta h}{L}; \quad (4.15)$$

$$\Delta h = h_1 - h_2\text{, m} \quad (4.16)$$

The structural average values of the water velocity in the unpaved canals are given in Table 4.8.

Table 4.8

Composite average values of water velocity in unpaved canals

Types of ground materials	v_{max}, m/s
Sandy loam: weak	0,7...0,8
Densed	1,0
Sandy soil: light	0,7...0,8
Average	1,0
Densed	1,1...1,2
Soil: soft	0,7
Normal	1,2...1,4
Densed	1,5...1,8
Gravel	0,5

Figure 4.20. Channel view of the channel lengthwise.

The water consumption (Q) of the canal is determined by the following formula:

$$Q = V \cdot \omega \text{, m}^3\text{/s} \qquad (4.17)$$

Or

$$Q = \omega \cdot C\sqrt{R \cdot i} \text{, m}^3\text{/s.} \qquad (4.18)$$

4.5. Hydraulic dams

A dam is a hydraulic structure designed to artificially raise the natural water level of a river or canal several times and collect water (Figures 4.20, 4.21, 4.22, 4.23, 4.24, 4.25, 4.26).

Dams are divided into 2 types according to the construction materials:

- *dams made of natural or local raw materials (up to 300 m);*
- *dams made of artificial raw materials.*

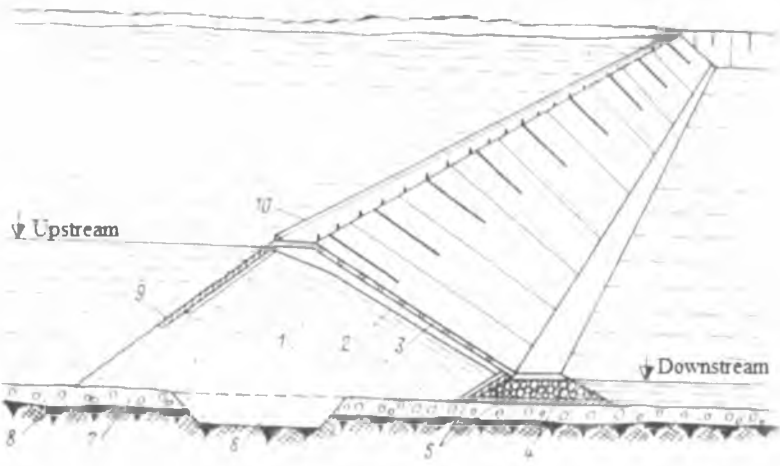

Figure 4.21. Homogeneous dam view:
1-dam; 2-surface of the water being filtered; 3-slope reinforcement; 4-drainage; 5-return filter; 6-teeth; 7-permeable soil; 8-waterproof soil; 9-stone-reinforced slope; 10-parapet reflecting the wave.

Dams made of natural or local raw materials are divided into the following types:

– *homogeneous - a dam built using only one raw material*;

Non-homogeneous - a dam built using multiple raw materials.

Homogeneous dams vary as follows:

– *rocky dams;*

– *stone dams.*

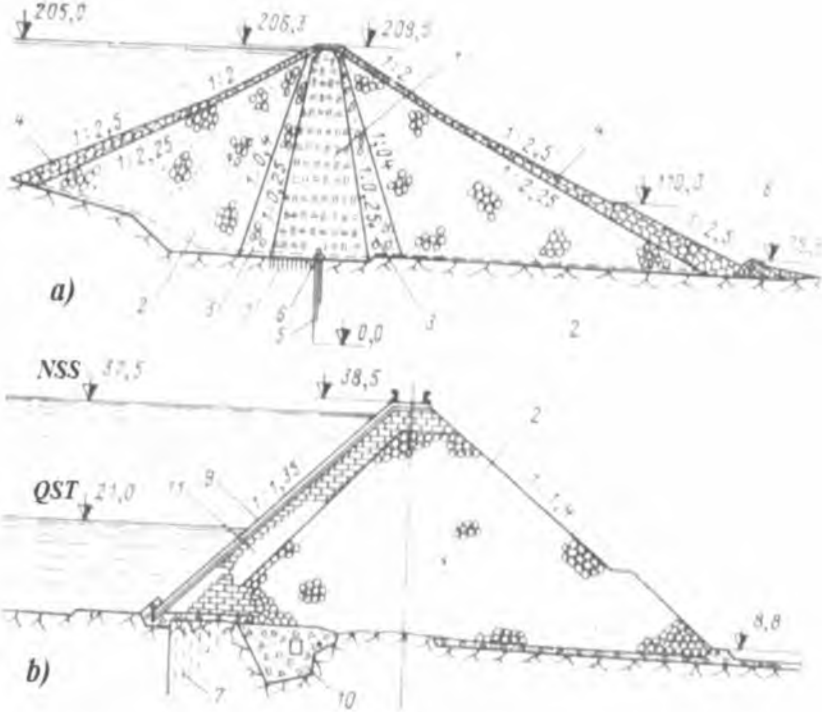

Figure 4.22. View of dams stone - ground (a) and stone throw (b): 1-core; 2-stone throwing; 3-conductive layer; 4-stone shed; 5-cement balancer; 6-cement gallery; 7-reinforcing cement; 8-bottom connector (drainage); 9-steel screen; 10-concrete tooth with cement galleries; 11-screen underlayment.

Dams made of artificial raw materials are divided into the following types:

- wooden dams (2 - 20 m);
- fabric dams (up to 5 m);
- concrete and reinforced concrete (more than 100 m).

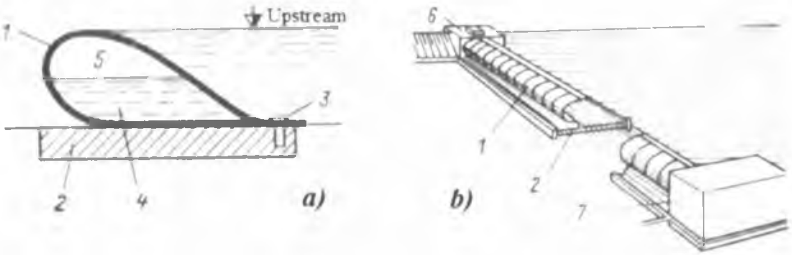

Figure 4.23. Fabric dam view:
a) a fabric dam that raises the water level in the canal; b) a fabric dam designed to provide the required suction height to the pumping station; 1 - fabric coating; 2 - concrete flyutbet (threshold); 3 - anchor reinforcement; 4 - water; 5 - air; 6 - coast; 7 - pump station.

There are the following types of concrete and reinforced concrete dams:

- gravitational;
- counterfeits;
- arched.

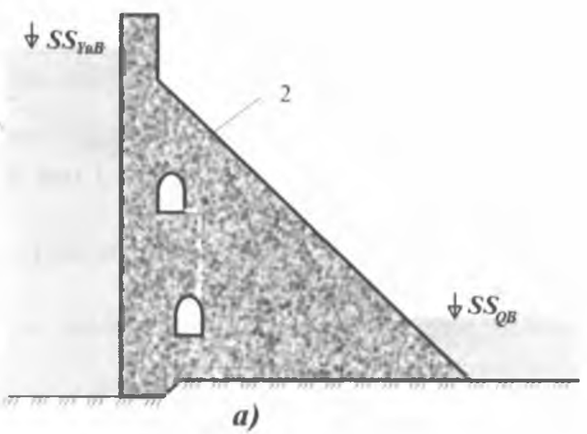

Figure 4.24. Gravitational dam: a - closed dam; b - the discharge dam.

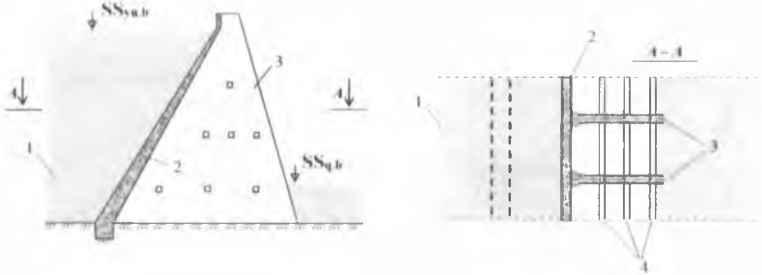

Figure 4.25. Counterfeit dam:
1 - reservoir; 2 - dam; 3 - buttresses; 4 - fastening beams.

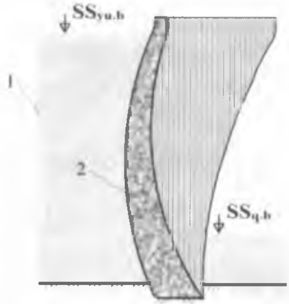

Figure 4.26. Archaic dam:
1 - reservoir; 2 - dam.

4.6. Reservoirs

Reservoirs are basins that are artificially constructed using hydraulic structures and occupy a large area on a very large scale and volume.

From a technical point of view, the redistribution of water resources is carried out using artificial reservoirs.

An artificial reservoir is a reservoir that collects water from dams in an open stream.

There are currently about 1,000 reservoirs in the CIS with a volume of 850 km^3, $V_{foid} = 414$ km^3.

Hydroelectric dams are built through dams. In front of the dam, the water level rises and a large volume of water (accumulation) is collected, which is distributed through engineering devices such as dams, locks, and drainage ditches.

Reservoirs have a length of distribution from the surface of the dam, which has its natural course and shoreline.

Reservoirs are classified differently:

Perennial, annual, monthly, weekly and daily ***water level adjustments***.

Geographically flat *(15 ÷ 35 m)*, ***pre-mountain*** *(50 ÷ 100 m)*, ***mountain*** *(200 m and above)* reservoirs.

Reservoirs for various uses:

• *power reservoirs, reservoirs where the mode of operation is determined by the requirements of the energy system;*

• *complex reservoirs, reservoirs, the mode of operation of which is determined based on the requirements of several industries.*

The scheme of the reservoir is shown in Figure 4.27.

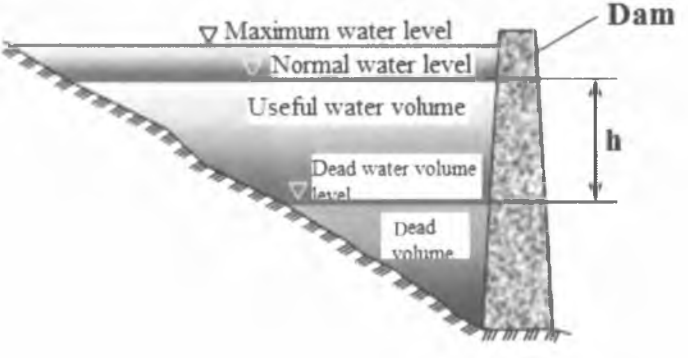

Figure 4.27. Reservoir scheme.

Depending on their location relative to HPPs, reservoirs are divided as follows:

• reservoirs located at the top, at the head of the river or stream where the HPP is located;

• private (relevant), i.e. reservoirs that are part of HPP facilities and connected to HPPs;

• reservoir HPP located below a river or water stream where the HPP is located.

Reservoir parameters are determined on the basis of water management calculations.

In this case, the volume of water is divided into useful and fixed parts.

The full size of the reservoir

$$V_{NSS} = V_{QSS} Q V_{useful} \tag{4.19}$$

The main characteristic of a reservoir is that the surface area F and the volume V depend on the water level N or its depth h. Curves are called F, V = f (H) or F, V = f (h).

If the water level in a reservoir is assumed to be horizontal, then the V = f (h) relationship is called a static relationship.

If the volume of a reservoir is determined by a free surface line with a level change (support), this connection is called a dynamic connection.

It uses topographic maps to build graphical connections.

$$V_H = \sum_{i=H_0}^{H} \Delta V_i \tag{4.20}$$

Average reservoir depth is calculated as:

$$h = \frac{V_H}{F_H}\ , \text{m} \tag{4.21}$$

Reservoir water loss is divided into evaporation, filtration, freezing and sluice, and additional evaporation.

$$h_{steam} = h_{wat.\ res.} - h_{dry}$$

The difference between the evaporation layer in a reservoir and a flooded area.

Reduced water evaporation

$$Q_{steam} = \frac{(h_{SOMB} - h_{dry})F_{steam}}{t_{<EU}} \qquad (4.22)$$

here, F_{steam} – evaporation area;

t_{steam} – open valley period (time).

Decreased filtration of water

$$Q_F = \frac{h_F \cdot F_F}{t_F} \qquad (4.23)$$

h_F – filtration layer;

F_F – filtration flow area;

t_F – filtration (period) time.

Reducing the amount of water to ice

$$Q_{MU} = \frac{\gamma_{MU} \cdot h_{MU}(F_{npU} - F_{Umm})}{t_{jSyJS}} \qquad (4.24)$$

γ_M, h_M – bulk density and ice sheet;

T_{winter} – continuation of the winter period.

Water depletion in the sluice

$$Q_{sluice} = \frac{l \cdot b \cdot h \cdot n}{t_{sluice}} \qquad (4.25)$$

l, b, h – length, width and height of the sluice chamber;

t_{Sh} – navigation period;

n – the number of gateways during navigation.

Control questions

1. How much water is in the hydrosphere?

2. How many HPPs are there in the country and what is their total capacity?

3. How is the amount of potential energy calculated?

4. Name the ten largest hydropower producers in 2009.

5. What is the formation of water resources used within the territory of Uzbekistan?

6. How is the slope of a river determined along its length?

7. Describe the channels, their types and functions.

8. What are the types of channels according to the cross-sectional area?

9. What purposes are the channels built for?

CHAPTER V. HYDRO ENERGY DEVICES, THEIR PARAMETERS AND EQUIPMENT

5.1. Hydraulic turbines

A hydropower device is a device that converts mechanical energy of current into electrical energy, or vice versa.

A hydraulic unit is a machine complex consisting of a hydraulic turbine (or pump) and a hydrogenerator (engine).

In a hydro turbine, hydraulic energy is converted into circulating mechanical energy, and the resulting mechanical energy is converted into electrical energy in a generator.

In a pump, the electrical energy in the motor is converted into circulating mechanical energy and the resulting mechanical energy into hydraulic energy.

There are two types of hydraulic units: vertical and horizontal. Types of hydraulic units are shown in Figures 5.1, 5.2, 5.3, 5.4, 5.5.

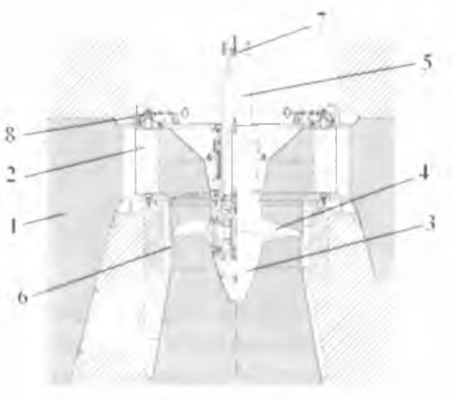

Figure 5.1. Training turbine unit image:
1 - concrete turbine chamber; 2 - router; 3-cone;
4 - impeller; 5 - shaft; 6 - working wheel chamber;
7 - flanged connection, etc.; 8 - servomotor lever.

Hydro turbines are divided into two types according to the principle of operation:

1. **Reactive - works using state energy and pressure energy.**
2. **Active - works when the water flow uses kinetic energy**.

Reactive hydraulic turbines:

Arrow - Twisted shovel (BK, N = 2-90 m) and Fixed shovel (JV, N = 1.5-80 m).

Radial axis (RA, N = 50-650 m).

Diagonal - (D, N = 70-150 m) includes hydraulic turbines.

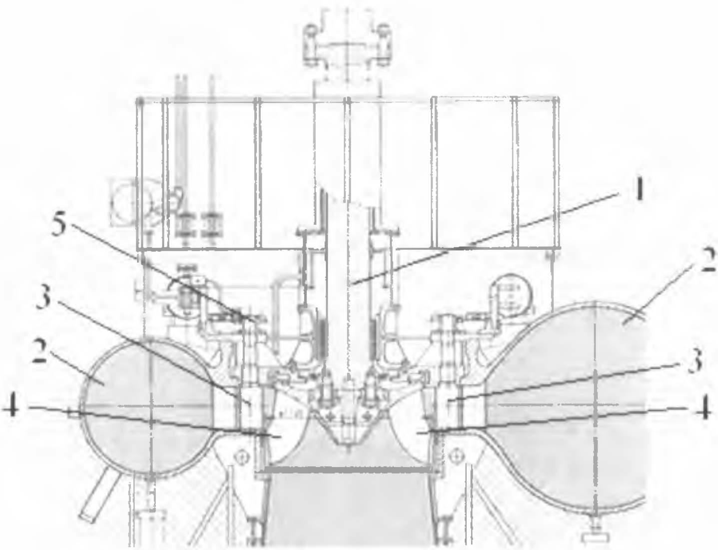

Figure 5.2. Illustration of a radial-axis turbine unit:
1 - shaft; 2 - metal turbine spiral chamber; 3 - router;
4 - impeller; 5 - servomotor lever.

Active hydraulic turbines include submersible hydraulic turbines (Ch, N = 300-1700 m and above).

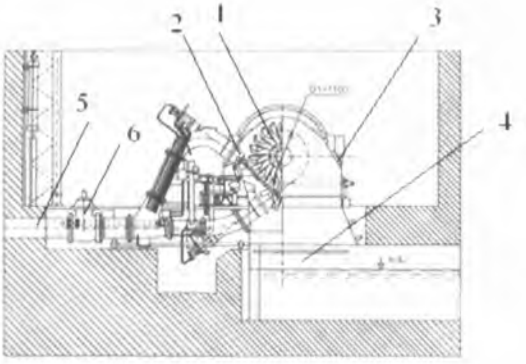

Figure 5.3. Image of a bucket turbine hydraulic unit:
1 - impeller; 2 - nozzle; 3 - cover; 4 - drainage channel;
5 - valve pipe; 6 - gate valve.

Depending on the location of the shaft, the hydraulic generators are located as follows:

– vertical (tick);

– horizontal (in some cases, i.e. capsule up to N = 25m);

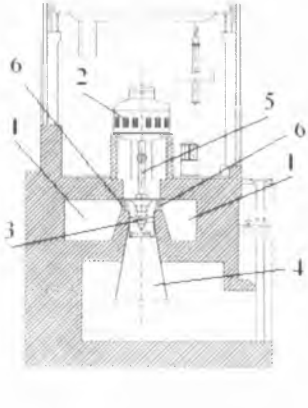

Figure 5.4. Vertical aggregate image.
1 - concrete turbine chamber; 2 -hydrogenerator; 3 - turbine;
4 - suction pipe; 5 - shaft; 6 - router.

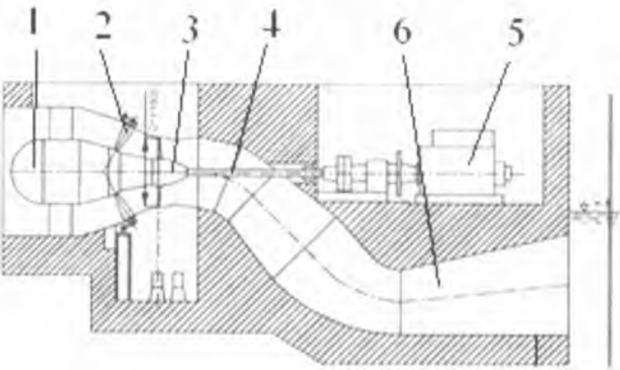

Figure 5.5. Horizontal aggregate image:
1- capsule; 2 - router; 3 - turbine; 4 - shaft
5 - hydrogenerator; 6 - suction pipe.

Downhill.

Vertical hydrogenerators are divided into umbrella (n0 <150 rpm) and suspension (n0> 150 rpm).

Horizontal hydrogenerators are used in hydroelectric power plants and hydropower plants with a pressure of $N \leq 20 \div 25$ m.

The flow rate of the turbine is equal to the amount of water transferred to the impeller chamber by means of a guide device.

$$Q = \frac{W}{t} = \frac{m^3}{sek};$$

here, W – the volume of water, m3; t – time, sec.

Equations can be used to determine turbine water pressure:

$$H = (Z_b - Z_h) - \frac{\alpha_3 V_3^2}{2g} - h_{b-h} \tag{5.1}$$

Here Z_b and Z_h – upper and lower byef levels; Vz – water velocity in the discharge pipe; αz – kinetic energy index; h_{b-h} – the value of pressure lost at the distance from the water pipe to the turbine chamber.

The power value of the turbine shaft is calculated according to the equation:

$$N = \rho g Q H \eta \tag{5.2}$$

here, ρ and g – water density and free fall acceleration; η – turbine useful work coefficient (uwc).

$$\eta = \eta_г \cdot \eta_d \cdot \eta_{mex} \tag{5.3}$$

here, η_g – turbine hydraulic u.w.c.; η_d – turbine capacity u.w.c.; η_m– turbine mechanical u.w.c.

The basic working equation of a turbine.

The amount of fluid flowing between the wings over time Δt can be determined by the following equation:

$$\Delta m = \rho \Delta V \tag{5.4}$$

here, ΔV – elementary water volume.

5.2. Pumps

Hydraulic machines are used to pump fluid in pipes. The pump takes mechanical energy from the motor and converts it into the energy of a moving stream of fluid.

Pumps are widely used in all sectors of the economy: machinery, metallurgy, chemical industry, agriculture, water supply, hydromechanization of agriculture and many other industries.

There are many types of pumps, the main ones being **dynamic pumps** and **volumetric pumps.**

In dynamic pumps, the fluid moves under the influence of hydrodynamic forces in a chamber that is in constant contact with the inlet and outlet parts of the pump.

In volumetric pumps, the fluid moves in a volume-varying chamber that alternates between the inlet and outlet parts of the pump.

Dynamic pumps can be divided into **rotary, inertial and friction pumps.**

In vane pumps, the movement of fluid is due to the energy given to the flow by the vanes during the rotation of the impeller. These pumps consist mainly of **centrifugal and axial pumps.**

In centrifugal pumps, the fluid moves radially from the center to the edge through the impeller.

In axial pumps, the fluid moves parallel to the impeller axis.

In friction and inertia pumps, the fluid moves due to friction and inertia. This group includes circulating, maze, flow, hydraulic tapping pumps and others.

Volumetric pumps can also be divided into two types: **rotary and reciprocating pumps.**

In rotary pumps, the working body moves without rotation. These pumps include gear, screw, auger and other pumps.

Forward-back pumps include piston, plunger and diaphragm pumps.

Basic pump parameters. The main parameters of the pump are its efficiency (water supply capacity) Q, pressure N, suction height, power N and efficiency (u.w.c.).

The amount of fluid delivered by a pump per unit time is called its **efficiency** (water supply capacity) and is expressed in m^3 / s, l / s, m^3 / h.

The pump pressure is the difference between the specific energy values of the fluid at its inlet and outlet, and is measured in meters (Figure 5.6).

$$H = E_H - E_B = \frac{P_H - P_B}{\rho \cdot g} + \frac{\vartheta_H^2 - \vartheta_B^2}{2 \cdot g} + (Z_H - Z_B) \qquad (5.5)$$

here, P_H and P_B – pressure values at the pump outlet and inlet, Pa (N / m3); ϑ_H and ϑ_B – average velocity values of flow from the pump to and from the pump, m / s; ρ – fluid density, kg/m^3; Z_H , Z_B – the vertical distance from the water level in the lower bay to the outlet and inlet of the pump, m.

The pressure at the outlet of the pump is measured with a manometer and the pressure at the inlet is measured with a vacuum gauge. In this case, the pump pressure is determined as follows:

$$N = M_H - V_B Q\ (\vartheta^2_H - \vartheta^2_B)/2g \qquad (5.6)$$

here, M_H, V_B – manometer and vacuum gauge readings, m. If the manometer and vacuum meter readings are in kgs / sm^2, then in order to turn them into *Pa* we should multiple it to *98066,5* .

Suction height. The distance from the bottom buffer to the pump shaft is called the **geometric suction height** of the pump.

$$H^G_{suck} = \nabla UpWL - \nabla DownWL\ ,\ m \qquad (5.7)$$

here, ∇ PShL – pump shaft level, m; ∇ DownWL – downsteam water level, m.

The **vacuum suction height** of the pump is determined as follows:

$$H^V_{suck} = H^G_{suck} Q\ \sum\Delta h_{suck}\ ,\ m \qquad (5.8)$$

here, $\sum\Delta h_{suck}$ – the value of the pressure loss in the suction line, m.

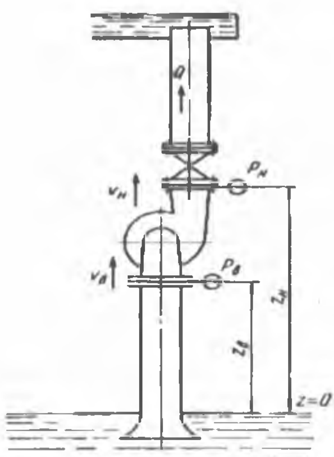

Figure 5.6. Scheme for determining the pump pressure.

Pump power. The effective power of the pump is determined as follows:

$$N_f = \rho g\,Q{\cdot}H\,,\ Vt. \qquad (5.9)$$

The power consumption of the pump is determined as follows:

$$N_{ist} = \rho g Q{\cdot}H/\eta_n\,,\ Vt \qquad (5.10)$$

here, Q, H – pump efficiency and pressure, η_n – pump u.w.c.

Efficiency of the pump. This value is determined as follows:

$$\eta_n = \eta_g{\cdot}\eta_m{\cdot}\eta_x \qquad (5.11)$$

η_g – hydraulic, which takes into account the values of hydraulic pressure loss in the pump u.w.c.

η_m – a mechanic who takes into account the mechanical resistance of the rotating parts of the impeller u.w.c.

η_x – volume, which takes into account the leakage of water from some parts of the pump u.w.c.

Pump u.w.c. varies from 0.88 to 0.92 for large pumps and from 0.6 to 0.75 for small pumps..

Bladed pumps, their types and structure
Centrifugal pumps

The pump suction line 6 and the impeller 1 must be filled with liquid before the pump can be started (Figure 5.7).

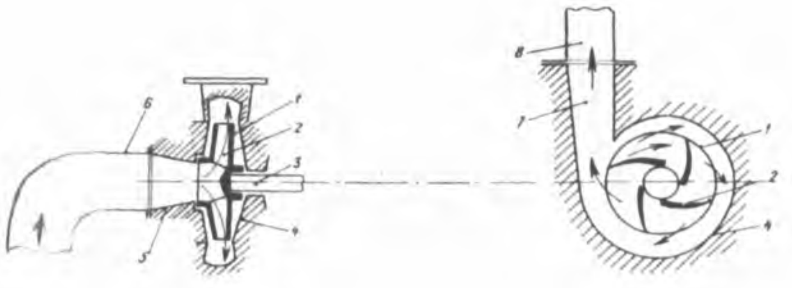

Figure 5.7. Scheme of a centrifugal pump:
1 - impeller; 2 - feathers; 3 - shaft; 4 - spiral drainage device; 5 - suction configuration; 6 - suction pipe; 7 - pressure diffuser; 8 - pressure line.

Then the engine starts and it turns the impeller 1. The fluid circulates with the wheel, under the action of a centrifugal force, from the center of the impeller to the edge, filling the spiral discharge device. At this point, reverse vacuum pressure is created at the entrance to the impeller.

As a result, the liquid enters the pump 6 from the suction pipe using atmospheric pressure acting on the lower byef water level, fills the central part of the impeller, and again a certain amount of fluid is expelled from the center to the edges of the impeller. This process continues uninterrupted, resulting in a continuous flow of fluid through a centrifugal pump.

As the fluid flows through the impeller, the mechanical energy of the engine is converted into the energy of the fluid flow.

The following types of centrifugal pumps are available.

1. Depending on the number of wheels: single-stage and multi-stage pumps. In multi-stage pumps, the fluid passes through a series of impellers. The pressure in these tires gradually increases to a certain level.

2. Horizontal and vertical pumps according to the position of the impeller.

3. Depending on the type of suction: one-way and two-way suction pumps (Figure 5.8).

4. Depending on the pressure: low pressure (up to 20 m), medium pressure (20-60 m) and high pressure (above 60 m) pumps.

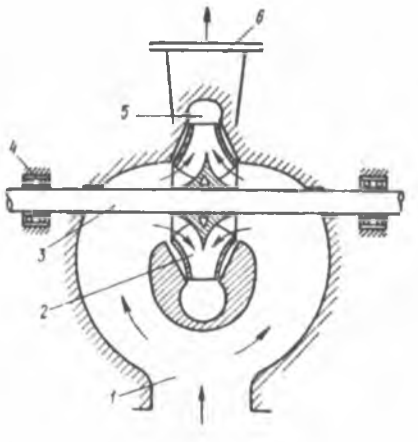

Figure 5.8. Two-way suction pump scheme:
1 - suction configuration; 2 - working wheel; 3 -shaft; 4 -bearings; 5 - spiral drainage device; 6 - pressure diffuser.

The pressure of single-stage pumps is up to 120 m, and the operating capacity is up to 15 m^3 / s. Multi-stage centrifugal pumps have a range of up to 2,000 meters and a throughput of up to 100 l / s.

The models of centrifugal pumps accepted in Uzbekistan are as follows:

1. Two-way suction pumps, for example D630–90 where D is two-way suction, 630 – efficiency, m^3 / h, 90 – pressure, m.

2. One-way, cantilever centrifugal pumps – for example, K200–125–330, where K – cantilever, 200 – diameter of the inlet of the pump, mm, 125 – diameter of the outlet of the pump, mm, 330 – working wheel diameter, mm.

A40GTS – 0.55 / 21, where A – aggregate, G – horizontal, 0.55 - productivity, m^3 / s, 21 – pressure, m.

3. Vertical centrifugal pumps, for example, 2400V – 25/40, where 2400 – diameter of the inlet of the pump, mm, V – vertical, 25 – efficiency, m^3 / s, 40 – pressure, m.

Axial pumps

Axial pumps have a capacity of 0.072–40.5 m^3 / s and a pressure of 2.5–26 m. The impeller of these pumps resembles a propeller, so these pumps are sometimes referred to as propeller pumps (Figure 5.9). The largest of these pumps, the main counter duct, is installed at the pumping stations. Axial pumps have two types of impellers. The A-type impeller blades are fixed so that the AR - axial rotary blade - type impeller blades are rotated, which allows you to change the operating mode of the pump. Axial pumps can be installed vertically and horizontally, and sometimes horizontally mounted pumps are housed in a special capsule. Figure 5.10 shows a schematic of an axial pump. The water flowing out of the impeller 1 has a slight circular motion. To guide it in parallel along the axis, a guide device 3 is installed after the impeller.

The following are the accepted models of axial pumps in the country:

1. For example, ARV10–260, where A – axial, R – rotating blades, V – vertical, 10 – modification number, 260 – diameter of the impeller, cm.

2. U50HS – 0.5 / 10, where U is the unit, 50 is the diameter of the pressure pipe, cm, H is horizontal, S is special, 0.5 is the working capacity, m^3 / s, 10 is the pressure, m.

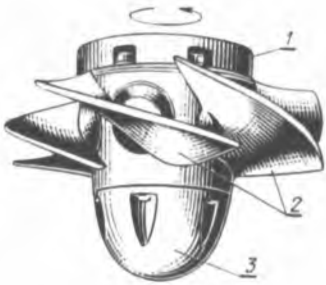

Figure 5.9. Axial pump impeller diagram:
1- bushing; 2 - wings, camera; 3 -cone.

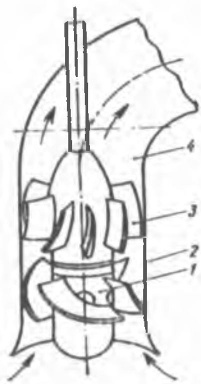

Figure 5.10. Axial pump diagram:
1 - impeller; 2 - camera; 3 - router;
4 - drainage device.

5.3. Hydroelectric power plants

Water management defines the measures of water resources, their calculation, use, conservation and treatment. Water supply consists of a river basin (for example, Syrdarya, Amudarya) and a lake or sea basin (for example, the Caspian Sea, the Aral Sea). The flow of water is adjusted, consumed and protected according to the size of the pool.

If the water flow is used only for electricity generation, the water industry is under the control of the HPP. In this case, the reservoir performs an energy function.

In **hydroelectric power plants** (HPPs), the hydraulic energy of water is converted into electrical energy (Figure 5.11). The parameters required for the operation of the HPP are water consumption Q, m^3 / s and the difference between the accumulated levels, the pressure N, m.

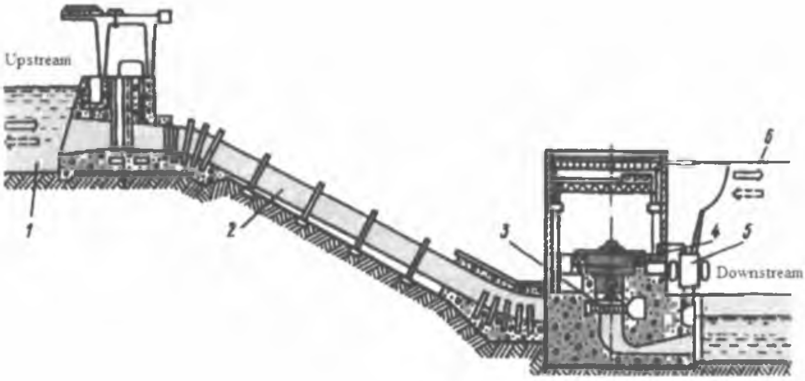

Figure 5.11. Overview of HPP:
1 - reservoir or lake; 2 - pressure pipe; 3 - turbine; 4 - generator; 5 - transformer; 6 - power transmission line.

The main structures of the HPPs on the plains are the dam and the station building. In hydropower plants, dams are built across the river to help raise the water level and create a large dam. The station building will house a hydraulic turbine, an electric generator, mechanical and electrical equipment. If necessary, hydropower plants can include water transport sluices, irrigation water intake facilities, water supply, fishing facilities, and more.

In a hydroelectric plant, water moves from the upper buffer to the lower buffer under the influence of gravity and rotates the hydraulic turbine, moving the rotor of the generator, which is located on the same shaft. In some cases, in generators with less power, additional transmissions (reducer or multiplier) are used to increase the speed and reduce the mass of the generator. The generator together with the turbine is called a hydraulic unit. It is the most widely used and most powerful hydropower plant in the world.[2]

Schemes of hydropower use in hydropower plants.

Hydropower is the main source of electricity for hydropower. For efficient use of water flow energy, it is necessary to place the difference in water levels over a relatively short distance.

The following schemes of formation of HPP pressure are available:

a) dam scheme;

b) derivation scheme;

c) dam-derivation scheme.

The dam scheme involves the construction of an artificial dam by blocking the waterway with a dam. This scheme is more suitable for large values of water consumption and small values of slope. The pressure created by the dam is equal to the difference between the upper and lower levels, that is $N_{HPP}=\nabla$ UpWL – DownWL. The water level in the upper bay is the water level directly in front of the dam (point V). Because this value is from the value at the starting point (point A) of the water basin Δh differs from (Figure 5.12).

Depending on the pressure in the dam scheme, HPPs can be located in the river or behind the dam. If the HPP is located in a river, it is part of a dam-forming structure along with the dam (Figure 5.13). In this case, the HPP building fully absorbs water pressure from the high bay and meets all the requirements for rigidity. In such hydropower plants, the load value is small.

If the pressure is 6 times the diameter of the turbine, then the HPP building cannot be considered as a water pressure receiver. In such cases, the HPP building will be built behind the dam and will not accept

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[2]Francesco Carrasco. Introduction to hydropower/ Published by: The English Press, Prakashdeep Bldg. Ansari Road, Darya Ganj, New Delhi, India, 2012

water pressure (Figure 5.14). Water is supplied to the turbines through special pipes located inside or over the dam, sometimes by passing it.

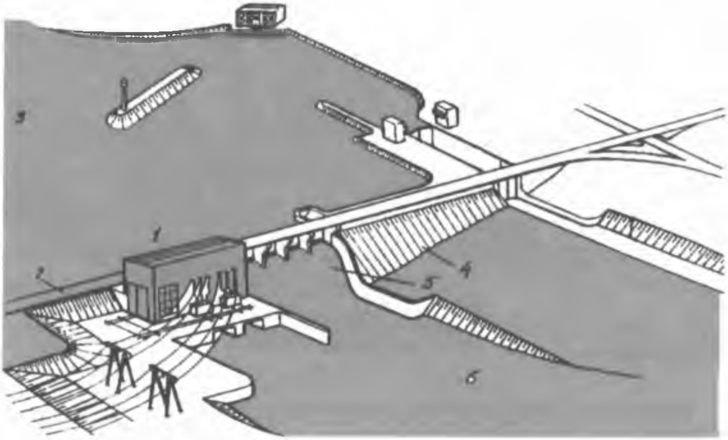

Figure 5.12. Hydropower dam scheme:
1 - water source; 2 - reservoirs; 3 - dam.

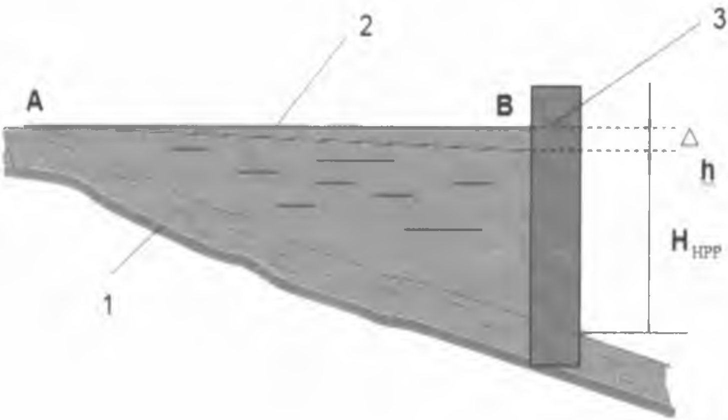

Figure 5.13. Scheme of the dam on the river:
1 - GES building; 2 - route; 3 - high byef; 4 - dam; 5 - downstream of dam; 6 - lower byef.

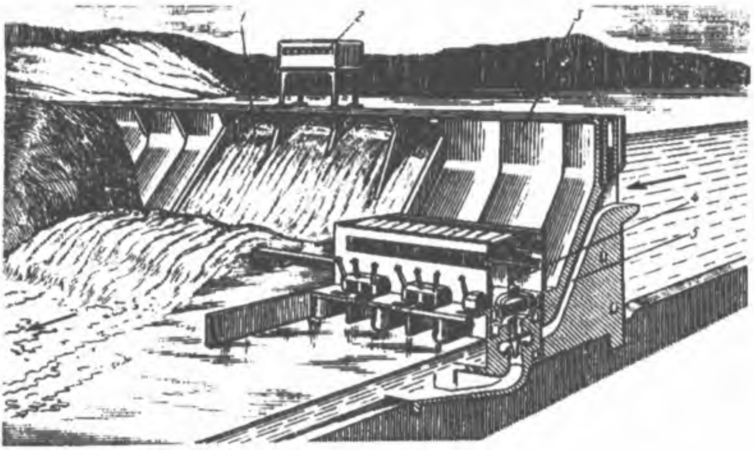

Figure 5.14. Schematic diagram of the HPP behind the dam:
1 - flood; 2 - water gate lift crane; 3 - station; 4 - HPP building; 5 - turbine pipeline.

Derivation scheme. This scheme is mainly used for water sources with a large slope. (Figure 5.15).

A relatively small dam will be built at the selected location of the water source and a small water basin will be formed. The water in the basin can also be fed along a natural source to a specially constructed diversion channel. The slope of the derivation channel is much smaller than the slope of the water source, and this difference is the pressure of the HPP. The derivation channel delivers water to the pressure basin and from there through pipes to the turbines. Water flowing from the HPP can be supplied to a source or any canal.

Dam derivation scheme. This scheme uses the capabilities of both of the above schemes. According to this option, a reservoir will be built on the riverbed, and derivation facilities will be used in the part after the dam. The dam diversion scheme is used when the slope of the water source is different. Where the slope of the source is small, a dam is constructed and a derivation scheme is used when the slope is large.

According to this scheme, the higher the dam is located above the HPP building, the smaller its size, as well as the size of the reservoir. But in this case the length of the derivation structures will increase significantly.

This means that the cost of the loss will increase. Therefore, the dimensions of the structures under the dam derivation scheme are determined by feasibility studies.

Generalized model of technological process of energy production in HPPs.

HPPs vary depending on the type, pressure, hydraulic scheme, mode of operation and other parameters.

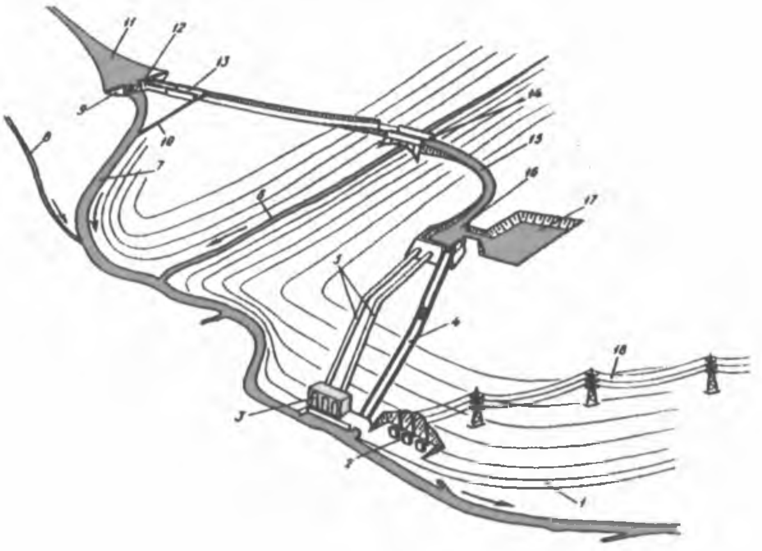

Figure 5.15. Derivative HPP scheme:
1 - line; 2 - substation; 3 -HPP building; 4 -drainage facilities; 5 - turbine pipes; 6 - left stream; 7-river; 8 - right stream; 9 - dam; 10 - sludge discharge facility; 11 - reservoir; 12 - water intake facility; 13 - silencers; 14 -aqueduct; 15 - derivation channel; 16 - pressure basin; 17 - adjustment basin; 18 - high voltage wires.

Therefore, the cost-effective use of hydropower resources is decided in accordance with the specific type of each HPP. Figure 5.16 shows a dam derivation scheme.

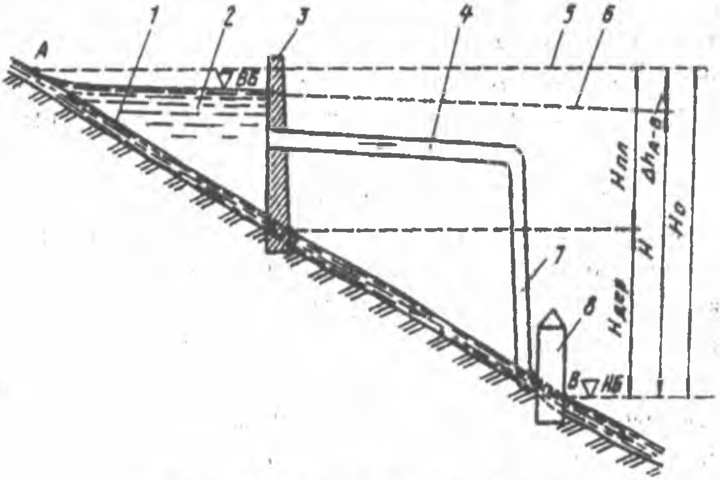

Figure 5.16. Dam derivation scheme:

$\Delta h_{A\text{-}B}$ - the value of the loss of pressure between points A and V;

1- riverbed; 2 - reservoirs; 3 - dam; 4 - derivation; 5 - hydrostatic level; 6 - piezometric line; 7 - turbine pipelines; 8 - HPP building.

The process of obtaining energy in hydropower plants is very complex and can only be studied by the method of orderly approximation. This means that HPPs are studied as separate technological processes. This separation of HPPs simplifies the problem of studying the characteristics of the regime and helps to understand the whole process model.

According to the method of orderly approximation, all energy losses in hydropower plants can be divided into technological and regime categories. The first includes all energy losses that occur in hydropower plants and are less time-dependent according to the technological scheme.

This energy reduction can be achieved by raising the level of design technology, construction and proper operation of hydropower plants.

The process energy loss is divided into the operation of the unit and the entire plant. The first is determined by the mode of the main hydraulic unit (loss of energy in the turbine, generator, pipeline block and others). The second depends on the mode of operation of all units of hydropower plants (losses in the upper and lower boreholes, derivation, general water supply, accidental flooding, etc.).

In the category of energy loss regime, the performance of hydropower plants is determined in conjunction with the reservoir. These losses include power at the entire plant, the optimal number of units and water supply facilities, pressure changes, and more.

To evaluate the effectiveness of hydropower plants, it is necessary to look at the absolute, comparative and differential types of regime indicators. Absolute values are N, Q, H, E, and so on.

Comparative indicators (ratio of absolute indicators) indicate the material volume of the technological process of HPP.

Differential indicators are subject to regime change and are widely used in optimization calculations, especially in the analytical solution of various HPP problems.

Figure 5.17 shows a generalized technological model of energy generation in reservoir derivations.

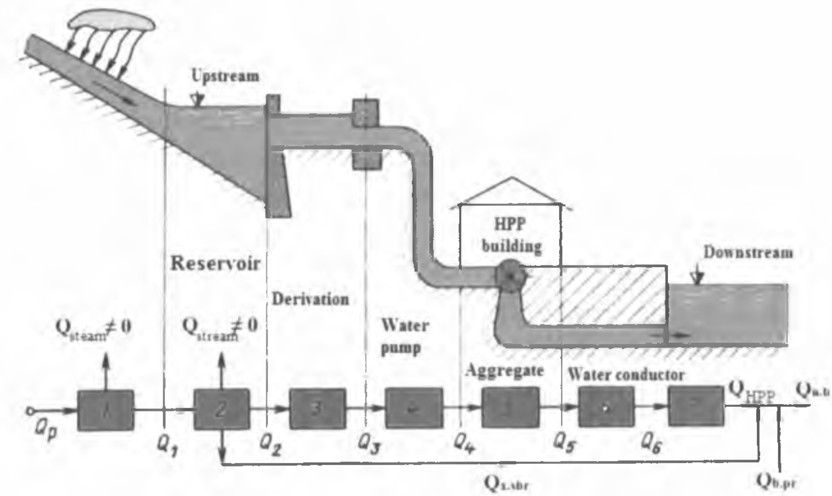

Figure 5.17. A generalized technological model of power generation in reservoir derivations.

The generalized technological model for derivation HPPs may include: 1-preparation of energy resources and delivery to the hydroelectric power station; 2 - collection and distribution of energy resources over time; 3 and 4 - transfer of hydropower to the hydro-aggregate by derivation and hydropower; 5-conversion of energy in hydraulic unit; 6 - discharge of water from the 6th hydraulic unit; 7-complete removal of water from HPP.

In this model, all stages are considered separately in terms of technological features, and water consumption is connected to each other by Q.

Each stage of the technological process of HPPs has indicators and characteristics that correspond to the type and nature of the station.[3]

[3]Francesco Carrasco. Introduction to hydropower/ Published by: The English Press, Prakashdeep Bldg, Ansari Road, Darya Ganj, New Delhi, India, 2012

HPP classification

Hydroelectric power plants are a complex of structures that convert hydropower into mechanical energy using hydraulic turbines and then into electricity using a generator. Hydropower plants operate according to the following schemes:

(a) Non-dam hydropower plants designed to use the kinetic energy of wastewater;

(b) dams built on the river to collect water pressure;

(c) branch hydroelectric power stations that deliver water to the turbine through a branch canal.

Branch HPPs can be dams or non-dams, respectively.

There are several types of non-dam power plants, such as coral reefs. At this power plant, several small-diameter turbines are attached to a single steel cable by means of couplings in a series of corals and are installed transversely or at a certain slope relative to the flowing water sources. An electric generator is attached to one end of the cable. As a result, when the turbines rotate, the cable also rotates together, and the electric generator generates electricity.

Such hydropower plants can be installed in ditches or rivers with a width of less than 0.5 meters, a depth of not less than 0.3 meters and a water velocity of more than 1 m / s, which can generate 1.5 kW.

They are submerged and can even be installed on rivers where steamships travel.

Coral power plants are subdivided into single-coral, multi-coral, longitudinal, and flexible turbine power plants.

Types of turbines used in coral hydroelectric power plants are as follows: bucket and others.

In hydroelectric dams, the water level is raised by a dam to create the required pressure. Stone, sand, clay, soil, etc. are used to build the dam. The drainage section of the dam will be made of concrete. Damcarrying structures (canals, pipes) are often constructed in the form of tunnels.

These devices vary in length. For example, the water of the St. Lawrence River on the lake brings water to the HPP through a 25 km long canal.

Hydroelectric power stations can be classified differently:

1. Depending on the capacity of HPPs:

microHPP - up to 100 kWh;

miniHPP - from 100 kWh to 1 MWh;

small HPP - from 1 MWh to 30 MWh;

medium HPP - from 30 MWh to 100 MWh;

large HPP - above 100 MWh.

2. Depending on the water pressure:

a) high pressure (more than 60 meters);

b) medium pressure (25 to 60 meters);

c) low pressure (3 meters to 25 meters).

Branch hydroelectric power plants are divided into non-dam (that is, water enters the turbine from the upper reaches of the river through a branch channel through a reservoir), and dams (water enters the turbine through a branch channel near the dam).

In dams, the pressure is increased by blocking rivers and raising the water level. Hydropower plants include a machine room with off-grid hydraulic units, automatic control and monitoring equipment.

Depending on the water pressure and the capacity of the hydraulic unit, the HPP building, i.e. the engine room, may be located differently than the dam. If such a hydroelectric power plant building is located on the right or left side of the dam together with its aggregates, or remains inside the dam, we call them dams or intra-dam hydropower plants. In these cases, because the HPP building is part of the dam, the hydrostatic forces acting on the dam are partially distributed throughout the building. Therefore, dam width and intra-dam HPPs will be constructed in such a way that the water level in the lower bay will rise to a certain part of the HPP building, as the end of the suction turbine in the lower bay will be below the water level. In some cases, the HPP building may be under the gutter. The HPP building will be connected to the high buffer by a spiral camera. The guide device that connects the spiral chamber to the turbine must adjust the water pressure to the turbine blades so that as much of the pressure as possible is used to move the impeller. Such hydropower plants are usually located in slow-flowing rivers with a water pressure of no more than 30-40 meters.[4]

5.4. Pumping stations

The class groups of pumping stations have several different options (Figure 5.18). Depending on the function of the PS, the natural conditions of the site, the parameters of the equipment installed at the station, the relative position of the facilities may be different.

The location of facilities and their design capabilities are determined by technical and economic calculations. In general, the following factors should be considered when addressing this issue:

– engineering-geological, topographic and hydrogeological conditions of the catchment;

– perfect (complex) use of water transmission facilities;

– possibility to use local working materials in construction and installation works;

– maximum unification of technical solutions in the construction of PS;

– the gradual completion of construction, the availability of facilities that have not yet been completed.

Maximum unification of technical solutions in the construction of PS:

[4]Francesco Carrasco. Introduction to hydropower/ Published by: The English Press, Prakashdeep Bldg, Ansari Road, Darya Ganj, New Delhi, India, 2012

– the gradual completion of construction, the availability of facilities that have not yet been completed.

The layout of the pumping station in relation to its building is as follows:

This scheme is adopted in order to build the PS building as close as possible to the irrigation area (to reduce the length of the pressure pipes) in the conditions of the flat relief of the pipeline.

Schemes of different types of pumping stations are shown in Figures 5.19, 5.20, 5.21, 5.22, 5.23, 5.24.

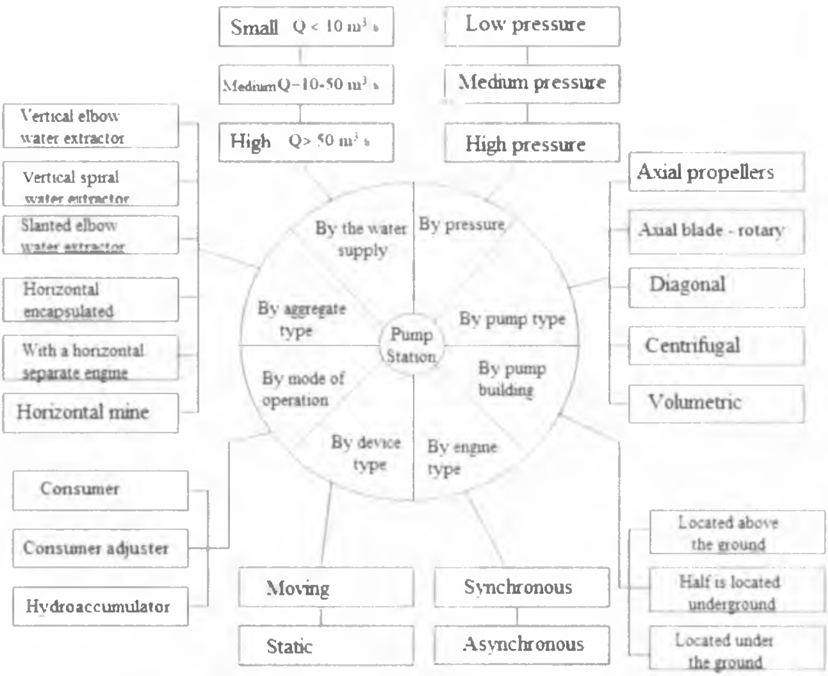

Figure 5.18. Class groups of pumping stations.

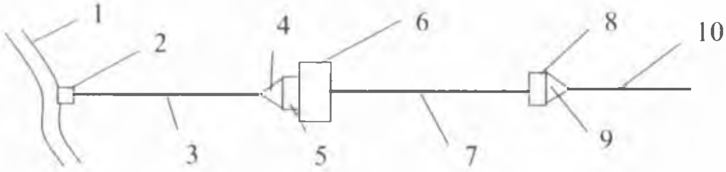

Figure 5.19. Derivation channel PS scheme:

1- water source; 2 - water intake facility; 3 - water supply derivation channel;4 - fore-chamber; 5 - water intake facility; 6 - PS building; 7 - pressure pipe; 8 -water extraction facility; 9 - pressure basin; 10 - channel with machines.

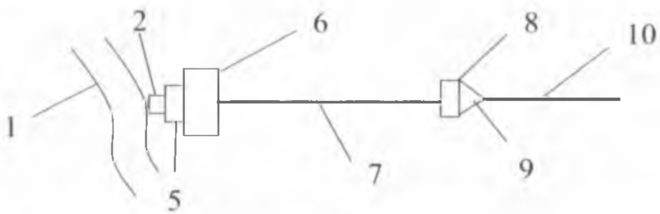

Figure 5.20. PS scheme combined with water intake structure:

1 - water source; 2- water intake facility; 5 -water intake facility; 6-PS building; 7 - pressure pipe; 8 -water extraction facility; 9 - pressure basin; 10 - channel with machines.

This scheme is acceptable for water sources with steep shores and amplitude of water level changes up to 5 meters.

PS scheme of the water intake facility located in the source bed.

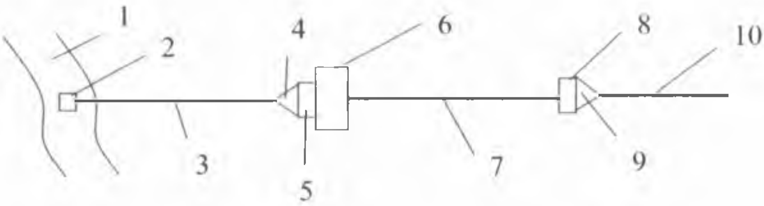

Figure 5.21. PS diagram of the water intake at the source:

1 -water source; 2- water intake facility; 3- water supply derivation channel; 4- fore-chamber; 5- water intake facility; 6-PS building; 7- pressure pipe; 8- water extraction facility; 9- pressure basin; 10-channel with machines.

This scheme is acceptable for coastal and water sources with large amplitude changes.

Schematic diagram of the water intake facility and PS building along the water source.

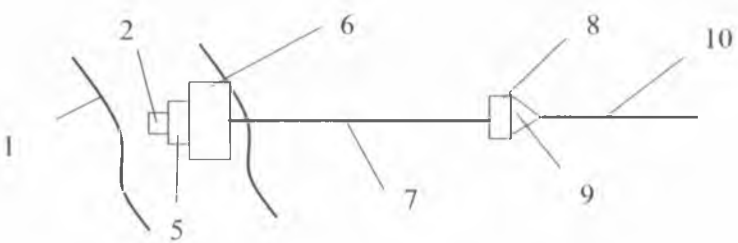

Figure 5.22. Water intake facility and PS building water source self-contained circuit:
1 - water source; 2 - water intake facility; 5 - water intake facility; 6 - PS building; 7 - pressure pipe; 8 - water intake facility; 9 - pressure basin; 10 - machine channel.

This scheme is adopted when the amplitude of changes in the water level in water sources is more than 8 meters and there are not enough conditions to see the structure on the shore.

Scheme combining the station building with the drainage system.

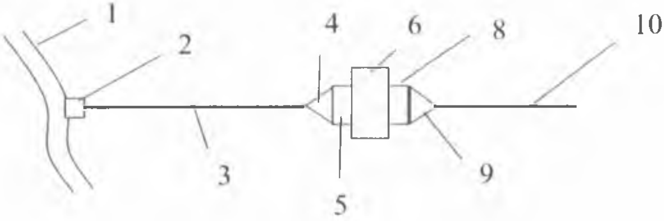

Figure 5.23. Water intake facility and PS building water source self-contained circuit:
1 - water source; 2 - water intake facility; 5 - water intake facility; 6 - PS building; 7 - pressure pipe; 8 - water intake facility; 9 - pressure basin; 10 - machine channel.

This scheme applies to low-pressure pumping stations.

Scheme combining water intake and discharge facilities with PS building.

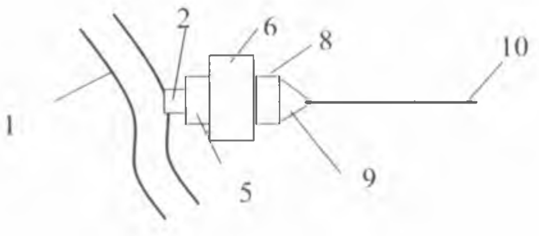

Figure 5.24. Scheme combining water intake and discharge facilities with PS building:
1 - water source; 2 - water intake facility; 5 - water intake facility; 6 - PS building; 8 - water intake facility; 9 - pressure basin; 10 - machine channel.

This scheme is suitable for PSs with a slope of up to 5 meters.

Ground pumping station building

This type of building is generally acceptable when the water level does not change significantly and the shoreline of the water source is strong. The floor of the building is slightly higher than the ground, and the pumps are mounted on a separate foundation (Figure 5.25). The building will be equipped with horizontal centrifugal pumps. In most cases, the pumps installed in these buildings are efficient $Q_H < 2$ m^3/sec.

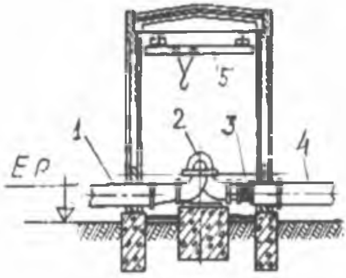

Figure 5.25. Scheme of an above-ground pumping station building: 1 -suction line; 2-pump; 3-lock; 4 - pressure line; 5 - lifting crane.

Half underground pumping station building

This type of building is acceptable when the amplitude of the change in water level exceeds the limited suction height of the pump. In this building, the pumps are mounted on a common foundation below the ground (Figure 5.26). Due to the fact that the pumps are located below the minimum water level, they are always filled with water, which makes it easier to start the pumps.

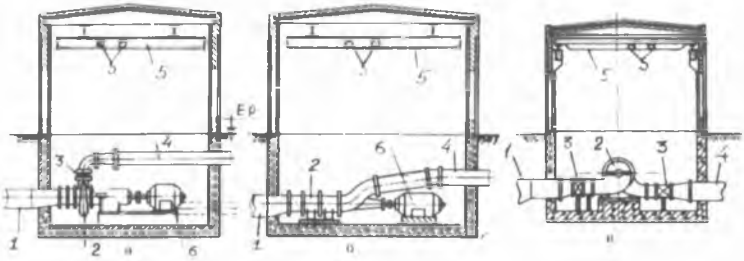

Figure 5.26. Half underground pumping station building: 1-suction line; 2-pump; 3-lock; 4-pressure line; 5-lifting crane; 6-electric motor.

Figure 5.26 shows schematics of pumping stations equipped with cantilever centrifugal (a), O-axis (b) and horizontal D-centrifugal pumps (c).

These buildings are mainly equipped with horizontal centrifugal pumps "0", in some cases vertical centrifugal pumps with a capacity of less than 4 m^3 / sec.

Block pump station building

This type of building is acceptable for any values of water level change (Figure 5.27). The building will be equipped with vertical pumps OP and V with a capacity of more than 4 m^3/s. In some cases, large D-shaped horizontal pumps may be used. The pumps have bent suction pipes, through which the water flows through a separate block from the beginning to the end. The pumps in the building are located below the water level, and the water intake is built in conjunction with the building. If low-pressure pumps are installed in the building, in some cases the building can be built in conjunction with the drainage system.

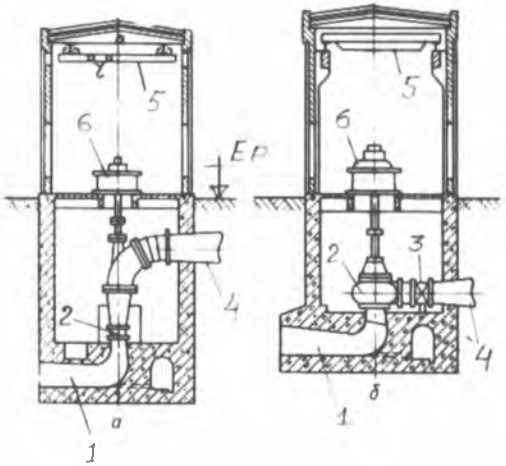

Figure 5.27. Block pump station building scheme:
a) a building with axial rotary blade pumps; b) a building with V-shaped centrifugal pumps;
1-suction line; 2- pump; 3-lock; 4 - pressure line; 5 -lifting crane; 6-electric motor.[5]

Basic parameters of the pump station

The main parameters of the pump station are its water supply efficiency – Q_{PS}, m^3/sec, pressure – *N*, m, power – *N*, *kWt* and efficiency ratio (UWC) – η_ni (figure 5.28).

The water supply efficiency of the PS is determined based on the number of pumps installed in it and their water supply efficiency. The number of pumps and their brand are calculated using feasibility studies in accordance with the water consumption schedule.

[5]Robert L.Sanks, Pumping station design/ University of Glasgow, *Butterworth-Heinemann*, USA, 1998

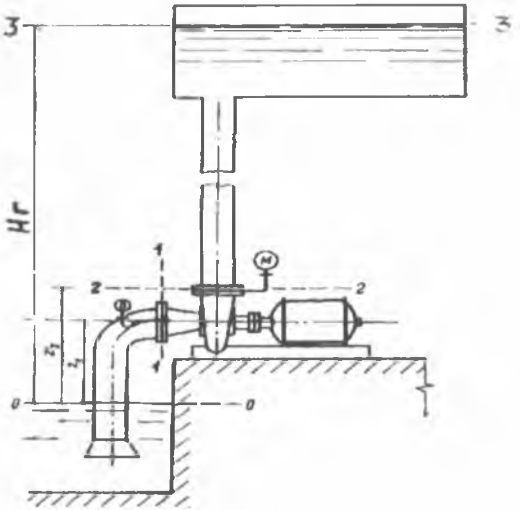

Figure 5.28. Determining the pressure of the pump station.

PS pressure. The geometric pressure of PS is equal to the difference between the upper byef water level and the lower byef water level.

$$N^{G} = \nabla UpWL - \nabla DownWL \qquad (5.12)$$

The full PS ratio is defined as follows:

$$N = E_{2\text{-}2} - E_{1\text{-}1} \qquad (5.13)$$

$E_{2\text{-}2}$, $E_{1\text{-}1}$ 2–2 and 1–1 the value of specific energies in sections

$$E_{2\text{-}2} = \frac{P_{2-2}}{\rho g} + \frac{\alpha \vartheta_{2-2}^{2}}{2g} + Z_{2} \qquad (5.14)$$

$$E_{1-1} = \frac{P_{1-1}}{\rho g} + \frac{\alpha \vartheta_{1-1}^{2}}{2g} + Z_{1} \qquad (5.15)$$

The pump station pressure is the joule value of the energy exerted by the pump on the 1 unit of gravity of the liquid.

To illustrate this, we observe a change in energy at sections 0–0, 1–1, 2–2, and 3–3.

According to Bernoulli's equation, the change in water flow energy between sections 0–0 and 1–1 can be expressed as follows: If section 0 - 0 corresponds to the lower surface water level, then section 1–1 is equal to the cross section of the water inlet of the pump.

$$\frac{P_{0-0}}{\rho g} + Z_{0-0} + \frac{\alpha \cdot \vartheta^2_{0-0}}{2g} = \frac{P_{1-1}}{\rho g} + Z_{1-1} + \frac{\alpha \cdot \vartheta^2_{1-1}}{2g} + \sum \Delta h_s \qquad (5.16)$$

However, as shown in Figure 5.28,

$$\frac{P_{0-0}}{\rho g} = \frac{P_\alpha}{\rho g};\ Z_{0-0} = 0;\ \vartheta_{0-0} \approx 0;\ \ Z_{1-1} = H_s$$

there $R_a/\rho g$ – altitude corresponding to atmospheric pressure, m; H_S – suction height, m.

In this case, formula (5.15) looks like this:

$$\frac{P_{1-1}}{\rho g} = \frac{P_\alpha}{\rho g} - H_s - \frac{\alpha \vartheta^2_{1-1}}{2g} - \sum \Delta h_s \qquad (5.17)$$

Based on (5.16), it can be stated that in section 1–1, that is, the pressure at the inlet of the pump must be less than the atmospheric pressure acting on the lower buffer surface. Otherwise $R_{1-1}/\rho g \leq 0$ but this is not possible, as the integrity of the stream will be compromised.

So, $\frac{P_\alpha}{\rho g} \geq H_s + \frac{\alpha \vartheta^2_{1-1}}{2g} + \sum \Delta h_s$ rule must be followed.

there $R_a \approx 0{,}1 MP_\alpha$ because it has value of:

$$(H_S Q \frac{\alpha\vartheta_{1-1}^2}{2g} + \sum \Delta hs) \leq 10m$$

We also express the energy change in sections 2–2 and 3–3 using the Bernoulli equation:

$$\frac{P_{2-2}}{\rho g} + \frac{\alpha\vartheta_{2-2}^2}{2g} + Z_{2-2} + \frac{P_{3-3}}{\rho g} + \frac{\alpha\vartheta_{3-3}^2}{2g} + Z_{3-3} + \sum \Delta h_b \quad (5.18)$$

So,

$$\frac{P_{3-3}}{2g} = \frac{P_\alpha}{\rho g}; \ \vartheta_{3-3} = 0; \ Z_{3-3} = H^G$$

In that case, 2 – 2 and 3 – 3 The change in energy in the sections can be written as:

$$\frac{P_{2-2}}{\rho g} + \frac{\alpha\vartheta_{2-2}^2}{2g} + Z_{2-2} = \frac{P_\alpha}{\rho g} + H^G + \sum \Delta h_b \quad (5.19)$$

here, $\sum\Delta h_b$ – the sum of the pressure loss values between sections 2 - 2 and 3 - 3 in the pressure pipe, N^G – pressure height, m.

To express the energy released from the pump $R_{2-2}/\rho g$ value must be determined:

$$\frac{P_{2-2}}{\rho g} = \frac{P_\alpha}{\rho g} + H^G + \sum \Delta h_b - Z_{2-2} - \frac{\alpha\vartheta_{2-2}^2}{2g} \quad (5.20)$$

The total pressure of the pump is shown in (5.13), (5.14) and (5.15)

$$H = E_{2-2} - E_{1-1} = \frac{P_{2-2}}{\rho g} + \frac{\alpha\vartheta_{2-2}^2}{2g} + Z_{2-2} - \frac{P_{1-1}}{\rho g} - \frac{\alpha\vartheta_{1-1}^2}{2g} - H_s \quad (5.21)$$

(5.20) to the link $R_{2-2}/\rho g$ and $R_{1-1}/\rho g$ We put the values found in (5.19) and (5.16):

$$H = \frac{P_a}{\rho g} + H^G + \sum \Delta h_b - Z_{2-2} - \frac{\alpha \vartheta_{2-2}^2}{2g} + \frac{\alpha \vartheta_{2-2}^2}{2g} + Z_{2-2} - \frac{P_a}{\rho g} + N_s + \frac{\alpha \vartheta_{1-1}^2}{2g} + \sum \Delta h_s - \frac{\alpha \vartheta_{1-1}^2}{2g} - H_s = H^G + \sum \Delta h_b + \sum \Delta h_s \quad (5.22)$$

Then, $\sum \Delta h_q = \sum \Delta h_S + \sum \Delta h_b$ the sum of the pressure loss values in the suction and pressure pipes, in which we write the connection (5.21) as follows.

$$N = N^G + \sum \Delta h_q \quad (5.23)$$

Thus, the total pressure of the pumping station is equal to the sum of its geometric pressure and the pressure loss values in the piping system.

The average weight values of the geometric pressure are determined by $N_{average}$ when the water levels change frequently in the upper and lower bays. This indicator is used to calculate electricity consumption.

There are also minimum and maximum values of the geometric pressure. The N^G_{min} value is used to calculate the installation height of the pumps, and the N^G_{max} value is used to determine the pumping efficiency.

The weighted average geometric pressure can be determined by the following formula:

$$H^G_{average} = \frac{\sum Q_i \cdot H_i^G \cdot t_i}{\sum Q_i \cdot t_i} \quad (5.24)$$

Here, Qi and $Ni - t_i$ water supply efficiency and geometric pressure value corresponding to irrigation periods, m.

H_i^G – the geometric pressure is defined as the difference between the upper and lower byef water levels:

$$H_i^G = \nabla UpWL_i - \nabla DownWL_i \qquad (5.25)$$

The change in the lower basin water level is determined based on the values of the annual change in the water source level.

In most cases, the water supply and drainage facilities are of the same size. In such cases, the change in water level can be determined on the basis of the graph Q = f (h), it should be noted that the value of the geometric pressure is constant at any value of water consumption, i.e. $H^G = const$.

So, in that case $H_{averag} = const$.

If the amplitude of the change in water level does not exceed 2 m, the value of HG can be equal to the average value of the maximum and minimum geometric pressure, i.e.

$$H^G = \frac{H_{max}^G + H_{min}^G}{2} \qquad (5.26)$$

The value of pressure loss in the pipeline system will be determined approximately before the design of the pumping station.

Design experience shows that the value of the pressure loss in local resistances can be assumed to be about 1.0–1.2 m. The value of the lost length is determined by the following formula.

$$\sum \Delta h_q = i \cdot L_k, \text{ m} \qquad (5.27)$$

i – specific value of lost pressure, m / m

i = 0, 003 ... 0, 004 m. For a pipe of length 1 m, Lk is the length of the pipe, km.

The capacity of the PS is determined by its water supply efficiency and pressure values. The PS determines the useful power and the power consumption:

$$N_{useful} = \rho g \cdot Q_{NS} \cdot N; \ Vt \qquad (5.28)$$

Consumption capacity of the pump station is calculated as follows:

$$N_{PS} = \frac{\rho g \cdot Q_{NS} \cdot H}{1000 \cdot \eta_N \cdot \eta_{DV} \cdot \eta_{TAR}}; kVt \qquad (5.29)$$

here, η_N – pump UWC; η_{DV}– engine UWC; η_{TAR}– power distribution network UWC.

The power value for pure water can be calculated by the following formula:

$$N_{NS}=\frac{9{,}81\cdot Q_{NS}\cdot H}{1000\cdot\eta_N\cdot\eta_{DV}\cdot\eta_{TAR}};kVt \qquad (5.30)$$

The efficiency of the PS is as shown in (5.28),

$$\eta_{ns}=\eta_n\cdot\eta_{dv}\cdot\eta_{tar}$$

determined by the connection.[6]

5.5. Hydroaccumulation power plants

Hydroaccumulation power plants (HAPP) Both of the above types of hydropower plants can function as a hydroelectric power plant and as a pumping station (Figure 5.29).

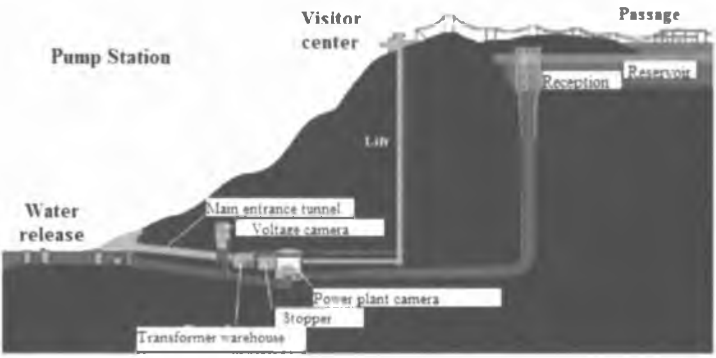

Figure 5.29. Scheme of Raccoon-Mountain HAPP.

[6]Robert L.Sanks. Pumping station design/ University of Glasgow. *Butterworth-Heinemann*. USA. 1998

At some point during the day (night), energy consumption is much lower than daytime energy consumption. At such times, the pumping units in the HAPP start up and fill the upper basin. During peak hours of the day, water flows from the upper basin to the turbines and generates electricity.

As a result, the pumps use cheap electricity to collect the required amount of water in the reservoir, which is used to generate more expensive electricity.

The efficiency of HAPPs is that they run on the energy system during the day at maximum values of morning and evening energy consumption, and at night they use cheap and sometimes unwanted electricity. HAPP can be adapted to not only daily, but also weekly and seasonal water regimes.

HAPP recovers 70-75% of the energy it receives from the grid due to various energy losses. By completing the HAPP night load schedule interruption and reducing morning and evening peak loads, NPP and TPP significantly improve maintenance performance and reduce the specific fuel consumption required to generate 1 kWh of electricity, resulting in a power grid allows to save fuel.

When the load on the HAPP power grid is reduced, it consumes electricity and pumps water into the upper basin, which acts as an accumulator. At the peak of the power grid, HAPP operates in turbine mode and generates electricity by discharging water from the upper basin into the lower basin.[7]

HAPP has the following class groups:

1) in terms of pressure value - low pressure $(H \leq 100\ m)$, high pressure $(H \geq 700\ m)$, moderate pressure $(H = 100 - 700\ m)$;

2) by type of hydropower device – pure HAPP, HPP – HAPP, HPP – PS;

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[7] Francesco Carrasco. Introduction to hydropower/ Published by: The English Press, Prakashdeep Bldg. Ansari Road, Darya Ganj, New Delhi, India, 2012

3) according to the layout of the HAPP building on the pipeline - at the beginning, in the distance, at the end;

4) by the number of reservoirs (reservoirs) - one basin, two basins, three basins;

5) by type of HAPP building - above ground, underground, semi-underground;

6) according to the scheme of aggregates - two-machine, three-machine and four-machine.

As mentioned above, depending on the type of device, HAPP can have pure schemes, HPP - HAPP, HPP - PS.

It is also called pure HAPP or simple accumulation (Figure 5.30).

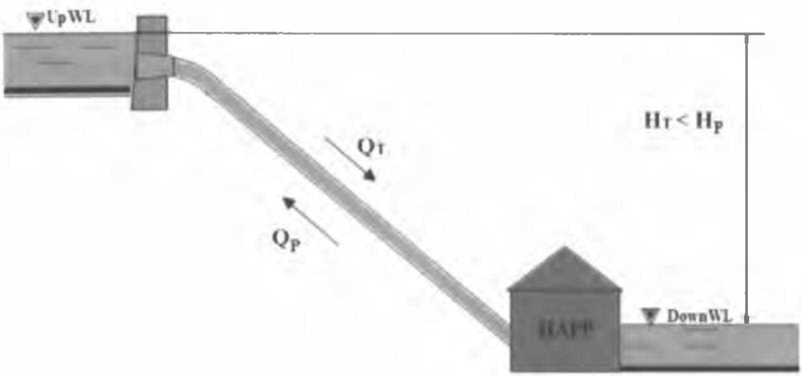

Figure 5.30. Scheme of pure HAPP.

This is the most common scheme, in which the water circulates in the device, which is pumped to the upper basin by means of pumps installed in it, and from there to the lower basin by turbines.

One of the peculiarities of this scheme is that the upper basin is not supplied with water from any other source. The smaller volume of water used for evaporation and filtration is replenished in the lower bay.

HPP - According to the HAPP scheme, the HAPP building will be equipped with turbines that generate additional energy in HPP mode in addition to the usual units. These turbines operate at the expense of the additional amount of water flowing into the upper water basin (Figure 5.31).

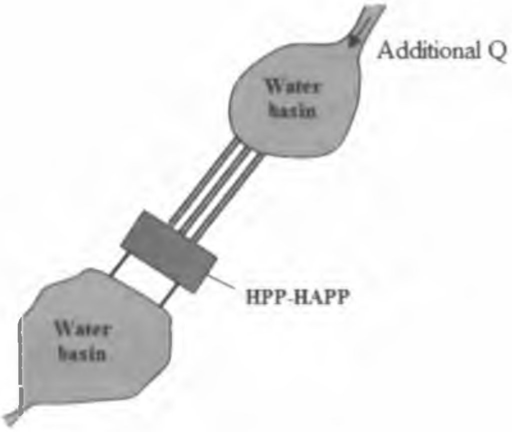

Figure 5.31. HPP - HAPP scheme.

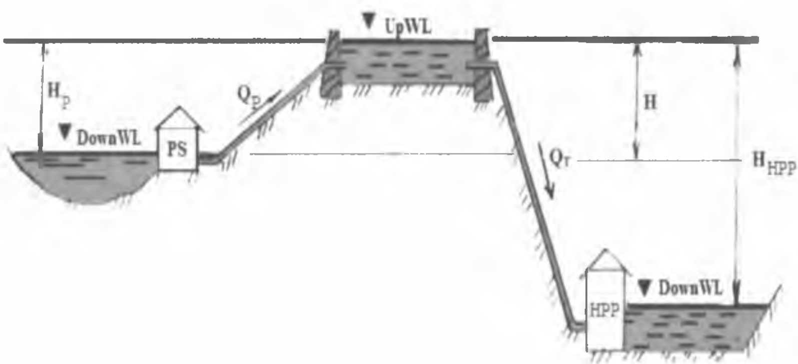

Figure 5.32. HPP - PS scheme.

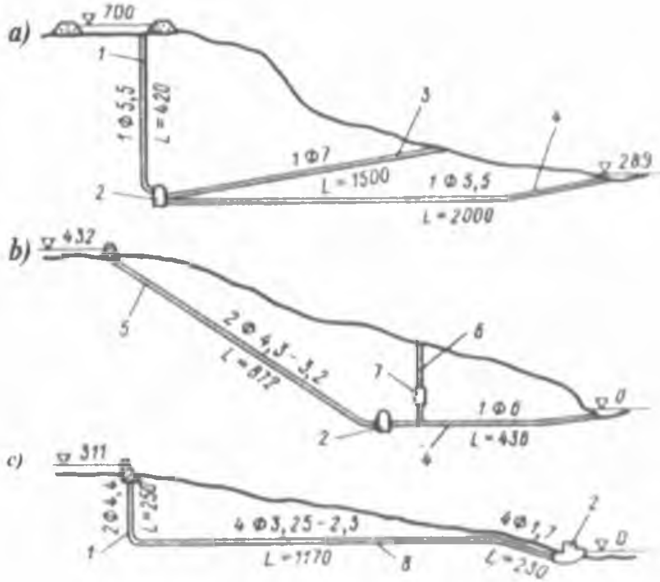

Figure 5.33. HAPP building relative to the pipeline layout scheme. a) at the beginning; b) in the interval; c) at the end; 1-vertical mine; 2-HAPP building; 3-transport tunnel; 4 - lower tunnels; 5-slope pressure pipeline (tunnel); 6 -airline; 7-equalization tank; 8- upper partially inclined tunnel.

In the HPP-PS scheme, in addition to the traditional two reservoirs, the third reservoir is also involved in power generation (Figure 5.32). To do this, a certain amount of water from the upper basin is transferred to a higher basin with the help of PS. This results in an additional increased pressure H for the HPP in front of the lower basin (Figure 5.33). Figure 5.34 shows a schematic of HAPP aggregates.

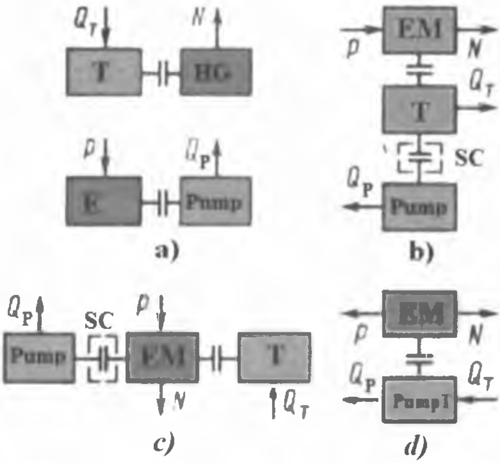

Figure 5.34. Schemes of HAPP aggregates:
a - four separate cars; b) and c) three machines (vertical and horizontal positioning); d - two machines; HG - synchronous electric machine (hydrogenerator); EM – electric motor; E - synchronous electric machine (engine); T - hydraulic turbine; Pump – pump; PumpT - pump-turbine; SC - special clutch; Q_T - turbine mode water consumption; Q_P - pump mode water consumption; N is the power produced; P is the power consumed.

Basic parameters of HAPP

The main parameters of HAPP are its capacity, pressure, amount of electricity produced per day and efficiency.

HAPP capacity. The difference between the upper byef water level and the lower byef water level is called the geometric pressure. The complete set of HAPP is called its geometric set. The total pressure of HAPP depends on its geometric pressure and the value of the pressure loss in the pipes. The total pressure value is higher in pump mode than in turbine mode $H_N \geq H_{tur}$.

This is because of the pump station and the HAPP full pressure detection formulas,

$H_N = H^G + \sum\Delta h_k$ va $\qquad H_{TUR} = H^G - \sum\Delta h_k$

HAPP power. The value of power depends on the flow rate and pressure of the unit. At night T time Q_H pump units operate with water consumption and $N_{N.R.}$ power consumption. Turbine during peak hours $N_{T,R}$ will have power.

$$N_{N.R} = \frac{\rho \cdot g \cdot Q_N \cdot H_N}{\eta_{N.R}};\ Vt \qquad (5.31)$$

there $\eta_{N.R}$ – pump mode HAPP UWC.

As mentioned in HAPP, $Q_N=(0,75....0,8)Q_T$, and napor values are as above, $H_N \geq H_T$

Therefore, the power values are different in both modes.

$$N_{TR} = \frac{\rho \cdot g \cdot Q_T \cdot H_T}{\eta_{T.R}}; Vt \qquad (5.32)$$

there, $\eta_{T.R}$ – turbine mode efficiency.

The amount of energy produced by HAPP per day is determined in the following order:

$$E_{T.R} = N_T \cdot T_T = \frac{V \cdot H_T \cdot \eta_{TR}}{367};\ kWt.hour \qquad (5.33)$$

there, V – the volume of water used in the turbine mode of the upper basin, m^3; H_T – turbine average pressure, m; η_{TR}– turbine mode FIK; N_T– HAPP turbine capacity, kWt. T_T – The time taken per day for HAPP to generate electricity, in hours η_{TR} = 0,86...0,87 T_T = 3....5 hours.

HAPP efficiency. HAPP efficiency is determined based on the values of electricity generated and consumed.

$$\eta = \frac{E_{TR}}{E_{NR}}; \qquad (5.34)$$

there, $E_{N.R}$ – pumped power consumption, [kWt·hour]

$$E_{N.R} = N_N \cdot T_N = \frac{V \cdot H_N}{367 \cdot \eta_{N.R}}; \quad (5.35)$$

there, N_N – The installed capacity of HAPP in pump mode, kWt; T_n – time of operation of HAPP in pump mode per day, hours.

The efficiency of modern large HAPPs is 75-78%. The efficiency of HAPP depends on many other factors, so its value can be found as follows.

$$\eta_{GAES} = \eta_T \cdot \eta_N \cdot \eta_{GEN} \cdot \eta_{ED} \cdot \eta_{Sh.Z} \cdot \eta_Q \cdot \eta_{Yu.V.L} \quad (5.36)$$

there, η_T – turbine UWC; η_N – pump UWC; η_{GER} – generator UWC; η_{EL} – electric motor UWC; $\eta_{Sh.Z}$ – personal needs UWC; η_Q – pipes UWC; $\eta_{Yu.V.L}$ – high voltage line UWC.[8]

5.6. Hydroelectric power plants

Although humans have known about rivers, seas, and oceans for thousands of years, little has been done to use the energy of the waves they generate. Although the energy of the waves generated in the seas is directly related to wind energy, wind energy is also directly related to solar energy. Figure 5.35 shows the waves hitting the shores of the ocean and sea.

The first patent for the use of wave energy was patented in 1799 (Paris). There are currently more than 1,000 different inventions and proposals for the use of wave energy (USA, UK, France, Russia).

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[8]Francesco Carrasco. Introduction to hydropower/ Published by: The English Press, Prakashdeep Bldg, Ansari Road, Darya Ganj, New Delhi, India, 2012

Figure 5.35. Ocean and sea waves.

However, the world's wave energy reserves are much smaller than solar energy. The world's ocean energy reserves (by various estimates) are estimated at 10 billion tons. kWh and 90 bln. kWh. However, this energy is only 2.7 billion kWh is considered useful, but this amount is approximately equal to the capacity of all power plants in the world and is 1.5 times more than the energy of rising and falling water. The conversion of wave energy into mechanical energy, which is a source of renewable energy, is one of the main challenges facing engineers. The energy of the waves, which can be converted into mechanical, hydraulic or other forms of energy, can be converted into electricity.

Waves in the oceans and seas, their dimensions and energy characteristics

Waves in the seas and oceans are mainly generated by wind.

Waves can also occur for the following reasons:

– in relation to the rise and fall of the water level (the changing forces of the moon, the earth and the sun);

– barometric (relative to sudden changes in atmospheric pressure);

– seismic tsunami (against strong earthquakes or volcanic eruptions);

– waves generated by the movement of ships.

In Figure 5.36, each wave is characterized by the following elements:

– the apex of the wave - the peak (the highest point of the ridge of the wave);

– the bottom of the wave (the lowest point under the wave);

– wave height - h (distance between the center of the wave and the bottom);

– wavelength - L (horizontal distance between two ridges);

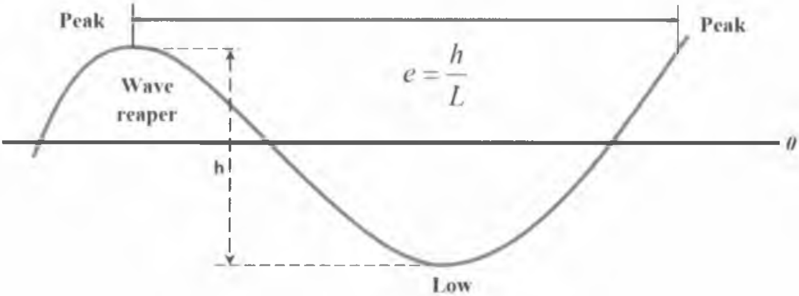

Figure 5.36. Elements of the wave.

– wave period - T (the time required for the wave to travel its own length);

– slope of the wave - e = h / L (ratio of the height of the wave to its length);

– is the steepest slope of the wave – δ=h/0,5L (the ratio of the height of the wave to its half-length);

– wave speed - S (the speed at which a wave travels a distance equal to its length);

– wave front (the planned length of a given wavelength).

In the open areas of the oceans and seas, the elements of the wave are calculated by the following formulas:

– wave height - $h = aW\sqrt[3]{D}$;

– wave length - $L = W\sqrt{D}$;

– wave speed - $C = 1{,}25\sqrt{L}$.

These are the coefficients a and z in the formulas, which depend on the depth of water (N) and are determined as follows:

$$\alpha = 0{,}0151\ N^{0{,}342};$$
$$z = 0{,}104\ N^{0{,}573}.$$

W is the wind speed; D is the wind speed.

The height of the waves depends mainly on the speed and acceleration of the wind.

The height of waves in the seas and oceans can range from 2 m to 18 m or even 30 m in the case of anomalies.

The unit of wave power is kWh / m, which takes into account the power of waves of length 1 m. The energy of the waves is much higher than that of the wind and the sun. The average power of waves in the seas and oceans is more than 15 kWh / m. For example, at a wave height of 2 m, their power can reach up to 80 kWh / m. The efficiency of wave energy is very high, which can be up to 85% in the conversion of mechanical energy into electrical energy.

Coastal waves and their energy characteristics

The energy of the waves hitting the shore is very high, which is mainly the kinetic energy of the wave. For example, at a height of 1 m and a length of 1 mile (1 nautical mile = 1853 m) every 10 seconds, the power of the waves is 35,000 horsepower (25,800 kW). The following are examples of the destructive energy of the waves crashing against the shore: pushed out of the white. Another 2,600-ton concrete block was replaced in five years. Engineers measured the strength of the waves hitting the site and found that the resulting pressure was 29 t / m2. The waves also threw a 60-kilogram piece of rock onto a 28-meter-high lighthouse on the Oregon coast.[9]

Wave power plants

There is a lot of information about the waves in the oceans and seas these days in movies, videos and television. They mainly feature athletes swimming on a sports board in the wake of the waves. But the depths of the sea and the ocean hold huge energy reserves. Wave energy can be used to produce mechanical, hydraulic and electrical energy. The mechanical and hydraulic energy generated by the waves can be used for various purposes, such as generating electricity, raising water, and so on. Such energy and its use have long been known to companies operating in this field. They are developing various types and devices to generate energy from sea waves. Such devices are currently operating in California, Oregon, Sweden, Scotland and Orkney Island (Figure 5.37).

Hydroelectric power plants (HEPP) generate electricity from energy generated by changes in sea level twice a day. Around the shores of some seas the level changes up to 10 m. The highest elevation is observed in the Gulf of Fandi, Canada, at 19.6 m (Figure 5.38).

In France, Rance HEPP (N = 240 MWh) was built. In the CIS, an experimental Kislogub (N = 400 kWh) HEPP is operating (Figure 5.39).

It is known that at some times of the day (night) energy consumption is much lower than the value of daytime energy consumption.

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[9]Francesco Carrasco. Introduction to hydropower/ Published by: The English Press, Prakashdeep Bldg. Ansari Road, Darya Ganj, New Delhi, India, 2012

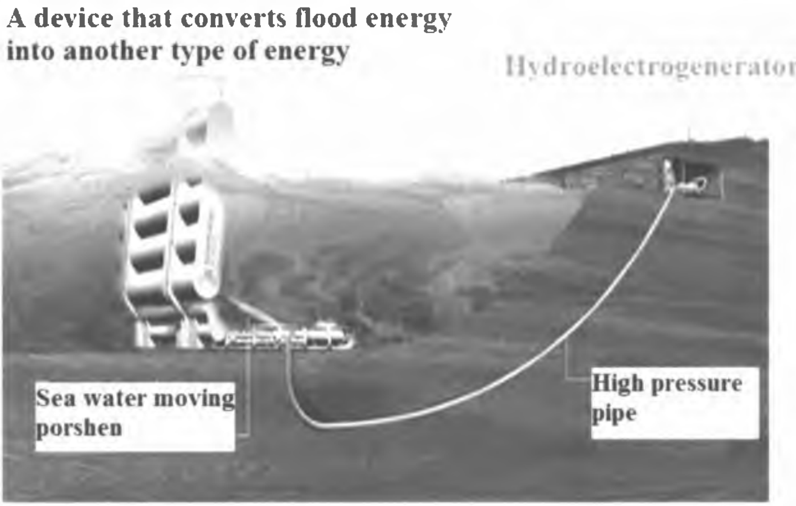

Figure 5.37. The Ustritsa device, which generates electricity using waves.

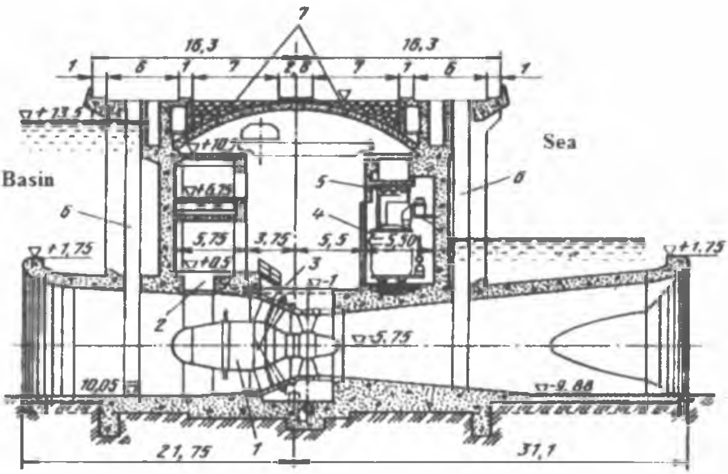

Figure 5.38. HEPP view:

1-capsule variable aggregate; 2 - hole for repairing an electric car;
3 - hydraulic machines; 4 - transformer; 5 - place of cable transmission to the open distribution device; 6 - flat gate; 7 – highway.

Figure 5.39. Pictures of Rans HEPP.

At such times, the units at HEPP are pumped and fill the upper basin. During peak hours of the day, water flows downstream from the upper bay basin, and the units are turbine-powered to generate electricity.

As a result, it consumes cheap electricity in pump mode and collects the required amount of water in the reservoir, which is used to generate more expensive electricity. The efficiency of HEPPs is that they operate on the energy system during the day at maximum values of morning and evening energy consumption, and at night they use cheap and sometimes unnecessary electricity. HEPP can be adapted to not only daily, but also weekly and seasonal water regimes.

By completing the HEPP night load schedule interruptions and reducing morning and evening peak loads, NPP and ThPP significantly improve maintenance performance and reduce the specific fuel consumption required to generate 1 kWh of electricity, resulting in provides economical fuel savings in the power grid.

Rance Tidal Barrage HEPP with a capacity of 240 MWh (24 hydraulic units) on the Rhine River in France is the largest HEPP in the world (Figure 5.40).

Its dam is 750 m long and covers an area of 22.5 km2. Rans paid $ 100 million for the construction of HEPP. The cost of electricity consumed and produced in euros is 1.8 eurocents / kWh.

The 254 MW Sihwa Lake Tidal Power Station is currently under construction in South Korea's Sixwa Sea.

In second place is the Annapolis Royal Generating Station HEPS with a capacity of 20 MWh in the Fandi Strait in Canada.

The largest wave turbine in the world is the 1.2 MWh SeaGen hydropower turbine at Strengford Laf, Ireland (Figure 5.41).

It is 16 m in diameter and weighs 300 t.

The world's largest wave power plant is the 2.25 MWh Agucadoura Wave Farm commercial wave power plant in Povua de Varzin, Portugal.

Half of the station looks like a submerged snake. It is 150 m long and 3.5 m wide (Figure 5.42).

Figure 5.43 shows an experimental Kislogub HEPP built in the CIS with a capacity of 400 kWh.

Figure 5.40. Rans HEPP layout.

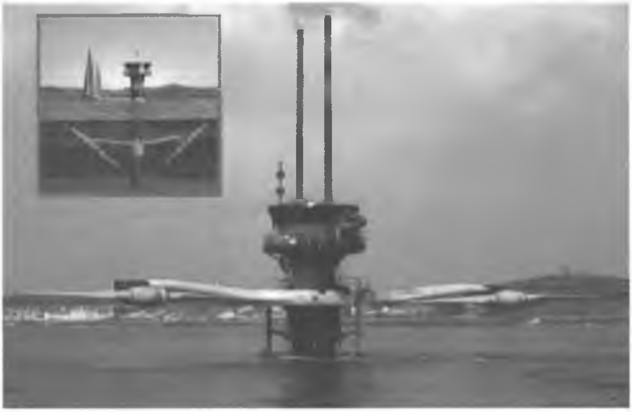

Figure 5.41. The world's largest 1.2GWh SeaGen wave turbine at Strengford Laf, Ireland.

It consists of 3 0.75 MW turbines. The price is equivalent to 13 mln dollars. It is planned to increase the capacity to 21 MWh.

Figure 5.42. The world's largest wave power plant, Agucadoura Wave Farm in Povua de Varzin, Portugal[10].

Figure 5.43. Experimental Kislogub HEPP with a capacity of 400 kW, built in the CIS.

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[10]Francesco Carrasco. Introduction to hydropower/ Published by: The English Press, Prakashdeep Bldg, Ansari Road, Darya Ganj, New Delhi, India, 2012

Control questions

1. What are the types of hydraulic turbines?

2. How many types of hydraulic units are there and how are they located?

3. What device is the pump?

4. Describe dynamic pumps and volume pumps.

5. Describe the main characteristics of pumps.

6. What types of centrifugal pumps are available?

7. What are the advantages of hydropower?

8. Tell us about the class groups of pumping stations?

9. Tell us about the pump station building located on the ground?

10. What are the functions of hydroaccumulation power plants?

11. Describe the main parameters of hydroaccumulation power plants.

12. Describe the waves in the oceans and seas, their size and energy characteristics.

13. What elements characterize each wave?

CONCLUSION

The textbook covers the general issues of training bachelors in hydraulic engineering - hydropower. In some cases, some sections of the textbook are presented in more detail, and some in accordance with the curriculum. Based on many years of experience, this textbook can be used by students in other fields of energy, especially for part-time and evening students.

Given the current energy generation technologies in the energy sector and the growing demand for it, its interaction with the environment can have very serious consequences.

The textbook also emphasizes the importance of hydropower in the economy and the high level of knowledge of bachelor hydropower to fulfill the high tasks set for its development. it is hoped that it will perform its function.

We hope that in the 21st century, Uzbekistan's energy sector will make a worthy contribution to the protection of the environment by fully utilizing the potential of hydropower, raising the economy to a higher level, and facilitating the fuel and energy sector.

Improving the effective combinations of design, construction and operation of hydraulic and renewable energy sources (HPP, HAPP, PS, HEPP) and ensuring their optimal joint operation of thermal and nuclear power plants. remains an economic and environmental task.

REFERENCES

1. O'zbekiston Respublikasi Prezidentining 2017-yil 27-fevraldagi PF-4947-sonli "O'zbekiston Respublikasini yanada rivojlantirish bo'yicha Harakatlar strategiyasi to'g'risida"gi Farmoni.
2. O'zbekiston Respublikasi Prezidentining 2017-yil 2-maydagi PQ-2947-sonli "2017–2021-yillarda gidroenergetikani yanada rivojlantirish chora-tadbirlari dasturi to'g'risida"gi Qarori.
3. O'zbekiston Respublikasi Prezidentining 2017-yil 26-maydagi PQ-3012-sonli "2017–2021-yillarda qayta tiklanuvchi energetikani yanada rivojlantirish, iqtisodiyot tarmoqlari va ijtimoiy sohada energiya samaradorligini oshirish chora-tadbirlari dasturi to'g'risida"gi Qarori
4. O'zbekiston Respublikasi Prezidentining 2017-yil 18-maydagi PF-5044-sonli "O'zbekgidroenergo" aksiyadorlik jamiyatini tashkil etish to'g'risida"gi Farmoni.
5. O'zbekiston Respublikasi Prezidentining 2017-yil 26-maydagi PQ-3012-sonli "2017–2021-yillarda qayta tiklanuvchi energetikani yanada rivojlantirish, iqtisodiyot tarmoqlari va ijtimoiy sohada energiya samaradorligini oshirish chora-tadbirlari dasturi to'g'risida"gi Qarori
6. O'zbekiston Respublikasi Prezidentining 2018-yil 17-apreldagi PQ-3672-sonli "O'zbekiston Respublikasi Suv xo'jaligi vazirligi faoliyatini tashkil etish chora-tadbirlari to'g'risida"gi Qarori.
7. O'zbekiston Respublikasining 2019-yil 21-maydagi O'RQ-539-sonli "Qayta tiklanuvchi energiya manbalaridan foydalanish to'g'risida"gi Qonuni
8. O'zbekiston Respublikasi Prezidentining 2019-yil 22-avgustdagi PQ-4422-sonli "Iqtisodiyot tarmoqlari va ijtimoiy sohaning energiya samaradorligini oshirish, energiya tejovchi texnologiyalarni joriy etish va qayta tiklanuvchi energiya manbalarini rivojlantirishning tezkor chora-tadbirlari to'g'risida"gi Qarori.
9. Аллаев К.Р. Энергетика мира и Узбекистана. Аналитический обзор. – Т.: Издательство «Молия» Банковско-финансовой академии, 2007: 388 с.

10. Непорожий П.С., Обрезков В.И. Введение в специальность: Гидроэнергетика: Учеб. Пособие для вузов. – 2-е изд., перераб. и доп. – М.: Энергоатомиздат, 1990. – 352 с.: ил.

11. Елистратов В.В. Возобновляемая энергетика/ В.В. Елистратов. – 3-е изд., доп. – СПб., Изд-во Политехн. ун-та, 2016. – 424с.

12. Использование водной энергии: Учебник для вузов/ Под ред. Ю.С. Васильева – 4-е изд., перераб. и доп. М.: Энергоатомиздат, 1995. 608 с.: ил.

13. Васильев Ю.С., Хрисанов Н.Н. Экология использования возобновляющихся энергоисточников. – Л.: Изд-во Ленингр. ун-та. 1991. 343 с.

14. Мухаммадиев М.М., Уришев Б. Гидроаккумулирующие электрические станции. – Т.: «Fan va texnologiya», 2018, 212 стр.

15. Francesco Carrasco. Introduction to hydropower/ Published by: The English Press, Prakashdeep Bldg, Ansari Road, Darya Ganj, New Delhi, India, 2012, ISBN 978-93-81157-63-3

16. Tiwari G.N., Mishra R.K. Advanced Renewable Energy Sources/ Indian Institute of Technology Delhi, New Delhi, India, 2012, ISBN: 978-1-84973-380-9John Ellis. Pressure transients in water engineering/ University of Glasgow, Thomas Telford Publishing Ltd, UK, 2008, ISBN: 978-0-7277-3592-8

17. Hermann-Josef Wagner, Jyotirmay Mathur. Introduction to Hydro Energy Systems: Basics, Technology and Operation, Springer-Verlag Berlin Heidelberg 2011, ISBN 978-3-642-20708-2

18. A.A.Irajpoor, Planning and Design of Hydro Electric Power Project. LAP Lambert Academic Publishing, United States, 2012, ISBN: 978-3-659-10723-8

19. R. Quentin Grafton, Karen Hussey. Water Resources Planning and Management. Cambridge University Press, United Kingdom, Cambridge, 2011.

20. Muhammadiyev M.M., Urishev B.U., Djurayev K.S. «Gidroenergetik qurilmalar». Darslik. –T.: "Fan va texnologiya", 2015.

21. Mamajonov M. Nasoslar va nasos stansiyalari. Darslik. – T.: "Fan va texnologiya", 2013.

22. Vasilev Yu.S., Muhammadiyev M.M., Tashmatov X.K. Gidro-energetik obyektlar ekologiyasi. O‘quv qo‘llanma – T.: ToshDTU, 2004.

23. Мухаммадиев М.М. и Потоенко К.Д. Возобновляемые источники энергии. Учебное пособие. – Ташкент: ТашГТУ, 2005.

24. Bakiyev M., Nosirov B., Xo‘jaqulov R. Gidrotexnika inshootlari. O‘quv qo‘llanma. – T.: O‘MKTM, «Bilim» nashriyoti, 2004.

25. Muhammadiyev M.M., Nizamov O.X. Gidroturbinalar. O‘quv qo‘llanma. – T.: ToshDTU, 2006.

26. Использование водной энергии: Учебник для вузов/ Под ред. Ю.С. Васильева. – СПб: Энергоатомиздат, 1995.

27. Елистратов В.В. Гидроэлектростанции малой мощности. Учебное пособие. – СПб.: Изд. Политехника, 2004.

28. Muhammadiev M.M., Uralov B.R., Mamajonov M. va boshqalar. Gidromashinalar. O‘quv qo‘llanma. – T.: TIMI, 2011.

29. AQSH Patenti 3.928.967 – To‘lqin energiyasi ishlab chiqarish apparati va usullari. Original «Salter's Duck» patenti.

30. AQSH Patenti 4.134.023 – Suv to‘lqinidan energiya ishlab chiqarishda foydalaniladigan apparatlar- «duck» samarasini oshirish uchun «Salter» usuli.

31. AQSH Patenti 6.194.815 — Pezoelektrik rotasion elektr energiyasi generatori.

32. AQSH talabnomasi 20.040.217.597 – Bosimlar farqi hisobiga ishlaydigan to‘lqin energiyasi konverteri.

33. http://www.gov.uz – O‘zbekiston Respublikasi hukumat portali.

34. http://www.catback.ru - научные статьи и учебные материалы

35. http://www.ziyo.net.uz

36. http://www.ges.ru

37. http://www.nasos.ru

38. http://www.energy.narod.ru

39. http://www.gidravl.narod.ru

40. http://www.allpumping.ru

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HYDROPOWER
(INTRODUCTION)

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