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# SIGNIFICANCE AND SCHEMES OF HYDROACCUMULATION POWER STATIONS IN ELECTRICAL POWER SYSTEMS

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**Abstract:** Today, the world is paying special attention to the field of hydropower. Among them, small-capacity hydro accumulation power plants occupy the most important place. In this article, the importance of GAES in the energy system is considered.

**Key words:** pumping plant, pump performance, water volume, plant power, operating mode, water tank.

Today, hydropower remains one of the main factors in the development of low-carbon energy. The main reasons for this are the harmful effects of hydrocarbon resources on the environment, the need to rely on renewable energy, including hydropower, due to the occurrence of an energy crisis due to various geopolitical reasons in countries that do not have these resources. It is recognized by experts, centers, organizations [1.].

At the United Nations climate change conference held in Glasgow in November 2021, global agreements were signed to ensure that the global temperature does not exceed $2^0$ C [1.].

In order to solve this global problem, authoritative international organizations, International Renewable Energy Agency (IREA), International Energy Agency (IEA), as a result of modeling the possibilities of hydropower in the world, have predicted an additional 850 GW of power by 2050, if climate change If it is necessary to provide up to $1{,}5^0$ C, they noted the need to develop 1200 GW of hydropower [1].

On September 21, 2021, at the World Hydropower Congress held in San Jose, the Declaration was adopted [1.]. In this Declaration, the fundamental concept that "Sustainable development of hydropower is a clean, ecological, modern and feasible solution to the issue of climate change" was defined, and it was emphasized that the main goal is to ensure the sustainable development of hydropower [1.].

In the report "Hydropower 2022: Industry trends and ideas" of the International Hydropower Association, it was noted that in 2021 the following goals were achieved in the field of hydropower in the world:

- the amount of electricity produced - 4252 TWh·h;
- installed capacity of hydroelectric power plant (HPP) - 1360 GW;

of which: hydroaccumulation power plants (HAPP) - 165 GW.

In 2021, the capacity of hydroelectric power plants increased by 26 GW,

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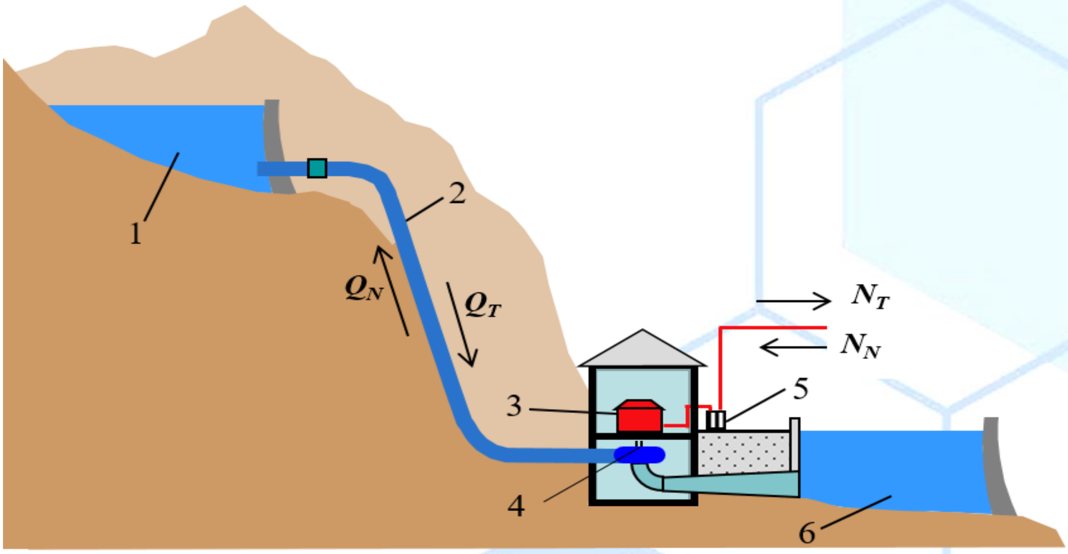
and the capacity of GAES by 4.7 GW [1.].

According to the conclusions of the International Hydroaccumulation Forum on the importance of HAPP in the energy system and their development in November 2020, "failure to develop reliable energy accumulation without the use of high-carbon gas turbines poses a real threat to energy supply" [1.].

According to the conclusions of the above-mentioned working group of the forum, HAPP are one of the main mechanisms for increasing the efficiency of energy systems. HAPP technology is recognized as the most effective technology due to the improvement of technology, the ability to store a large amount of energy, and the low cost of storage [2.].

Today there are more than 20 types of HAPP. Among them, the most widely used (especially in small-power HAPP) "pure" HAPP scheme is presented in pic. 1.

HAPP work process is carried out in the following order. When the energy consumption is low or the produced electricity is in excess, the pumping device at the HAPP is activated and the required amount of water is pumped from the lower reservoir to the upper reservoir for a certain period of time.




1 – upper water basin; 2 – pressure pipe; 3 – generator (electric motor); 4 – hydro turbine (pump); 5 – transformer;
6 – lower water basin.

**1 – picture. HAPP scheme**

At times of maximum energy consumption or when the amount of energy produced by the base power stations is insufficient, the water collected in the upper basin is fed to the hydro turbines of the HAPP and the necessary electricity is produced. Therefore, both HAPP and hydroelectric power stations act as pumping devices. For this, in HAPP, a four-machine consisting of a hydro turbine and a generator connected to it, a pump and an electric motor connected to it, a hydro turbine installed in series

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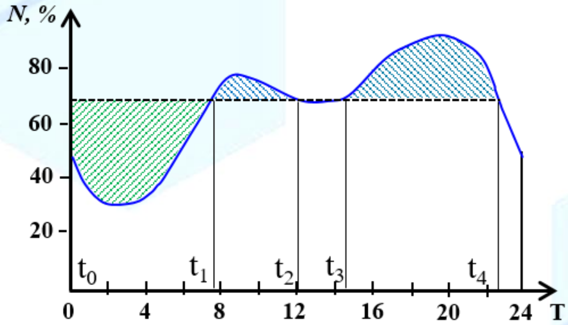
on one shaft, a three-machine machine consisting of a pump and a motor-generator, a double (rotary) hydro machine located on one shaft and two-machine circuits consisting of an engine-generator are used. In this case, the engine-generator consists of one electric machine, and both the engine and the generator work in modes. A double machine, in terms of construction, performs the function of both a hydro turbine and a pump [3].

HAPP are used in electric power systems (EPS) to effectively adjust the production process of electricity, bring its quality to the required level (adjust the voltage frequency) and as a quick backup power. The work of HAPP in this system can be expressed on the basis of the following schedule of daily operation of EPS (pic. 1.2).




**2 – picture. Performance graph of HAPP in EPS**

The graph shows an approximate example of the daily energy load of EPS in the form of a curve, which means that the power plants should work in such a variable mode during the day, for this, a number of energy units are shut down due to the minimum load in the interval from $t_0$ to $t_1$, later, it should be started again, and in the interval from $t_3$ to $t_4$, additional fast-starting power units, except for HPP, should be started and turned off again after $t_4$. This mode of operation is very inconvenient for thermal power plants, it leads to excessive fuel consumption and their rapid failure due to switching off and on of units [4].

According to the information of Talimarjon TPP unitary enterprise, during 2017, the K-800-240-5 energy block was stopped and started 5 times, and 1601 thousand $m^3$ of gas was consumed for this, which means that 320 thousand $m^3$ of gas was consumed for each start-up process. [4.].

Table 1 below shows the operating parameters of some thermal energy devices [4.].

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Table-1

**Performance indicators of heat energy devices**

| Device type | Parking time, hours | Start-up of the generator, hours | Time to reach full power, hours | Fuel consumption at start-up, tons |
|---|---|---|---|---|
| K-160-130 | 6...8 | 1,5 | 2,5 | 35 |
| K-200-130 | 6...8 | 1,5 | 2,5 | 45 |
| K-300-240 | 6...8 | 2,0 | 3,5 | 60 |

During the start-up of the units, the temperature state of the elements of the turbine, boiler and steam pipes are different, because their cooling rate is not the same, so they fail quickly when there are many such cases [5]. As a result, 25 percent of the accidents that occur in TPP occur due to malfunctions that occur during the start-up of units [5.].

In order to overcome these problems, HAPP are used in developed countries. The operating mode of HAPP is given in the graph of daily energy load of EPS in pic. 1.2. In the interval from $t_0$ to $t_1$ in the graph, the TPP units provide energy to the power system at a power corresponding to approximately 68% of the maximum power without shutdown, in which case the excess $N_{ES} – N_{YuG}$ power is supplied to the HAPP pumping devices and a certain amount of water is transferred from the lower reservoir to the upper reservoir $t_1$ - It is driven in time $t_0$ (where $N_{ES}$ is the power of power plants, $N_{YuG}$ is the power of the load graph). The volume of water collected in the upper reservoir is supplied to the HPP in the intervals $t_2$ - $t_1$ and $t_4$ - $t_3$, and the electricity required for EES is produced. In this case, the capacity of the TPP remains unchanged at the level of 68%. So, the volume of water pumped into the upper reservoir during the time interval $t_1$ - $t_0$ should be sufficient for the production of electricity required in the intervals $t_2$ - $t_1$ and $t_4$ - $t_3$.

As can be seen from the graph, the power of the TPP remains the same throughout the day, which is an ideal condition for power units, fuel consumption is minimal, and the stations work stably. However, it is difficult to operate stations at a constant power during the day in large energy systems, but it is possible to maximally smooth their load graphs using HAPP.

In many EES abroad, the price of fuel consumed during the hours of minimum energy consumption at night is much cheaper than the price of fuel used during the hours of maximum energy consumption in the evening.

In addition, the fuel consumption at the two times of the day is different, that is, when the energy consumption is minimal, the relative consumption of fuel in energy units is equal to 0.25...0.27 kg/ (kWh) lsa, it is equal to 0.5 kg/ (kW·s) on average at times of high energy consumption [5.].

Therefore, the use of HAPP allows to significantly reduce fuel costs in thermal power plants.

Based on the analysis of the above-mentioned literature and the opinion of experts in the field of the use of HAPP stated in the sources, the use of HAPP in EES has the following advantages:

- Saving fuel in thermal power plants and improving the operating condition of aggregates;
- reduction of unnecessary loss of electric energy due to reduction of transmission of electric energy over long distances in the energy system;
- cost reduction in power transmission systems;
- increase in energy system reliability (power reserve);
- increase in energy system stability and smoothing of the daily energy load graph;
- an increase in the quality of electricity (frequency and voltage of electric current);
- Use of HAPP as a source of reactive power (synchronous compensator);
- improvement of environmental conditions.

The world experience of using HAPP in different latitudes of the world reliably proves their technical efficiency in ensuring the economy of energy systems, which is mainly expressed in the increase in the reliability of electricity supply and the quality of electricity [6.].

Currently, there are more than 460 HAPP in the world, with installed capacities ranging from 100 MW to 3003 MW (Bass County HAPP in Virginia, USA) and with a head of several tens of meters to 1700 meters (HAPP Reiseek - Austria). total installed capacity is 165 GW [6.]. By 2023, the world's largest 3600 MW HAPP is expected to be Feng's HAPP in China [7.].

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