E3S Web of Conferences **264**, 04056 (2021) https://doi.org/10.1051/e3sconf/202126404056
CONMECHYDRO - 2021

Methodology for substantiation of technical and economic indicators of PSPP in energy water management systems of Uzbekistan

Muradilla Mukhammadiev*, *Kurbon* Dzhuraev, *Sanjar* Juraev, *Abdurauf* Abduaziz Uulu and *A* Makhmudov

Tashkent state technical university, Tashkent, Uzbekistan

Abstract. In our country, a lot of attention is paid to the development of the energy sector. A lot of work is underway to modernize existing capacities and commission new capacities. At the same time, the unit capacities of units and power plants also increase, which ensures faster commissioning of capacities in the power system and an increase in the efficiency of power plants. Attention is also paid to the development of power plants based on renewable energy sources (hydraulic, solar, wind, etc.). One of the most important tasks in the power industry is to cover peak minimum and maximum loads, which is becoming increasingly important in connection with the growth of the power system's capacity. As is known, according to world indicators, the maneuverable capacities should be about 25% of the total power of the EPS. The most promising maneuverable capacities are hydroelectric power plants. However, in our country, hydroelectric power plants account for about 14.3%. This task will become more complicated with the introduction of capacities based on solar and wind energy and the commissioning of new hydroelectric and thermal power plants in the Republic. This is because RES capacities have a significant discontinuity even during the day, and the water resources in the Republic are primarily for irrigation and drainage purposes and are significantly variable during the season. One way to solve these problems in the world is the creation and use of pumped storage power plants (PSPP). The peculiarities of the creation and use of pumped storage power plants in our region are that the available hydro resources of our region are mainly of water management importance, while the task is also to increase the energy efficiency of existing reservoirs. Based on the foregoing, we can say that the development of methods for determining the economic efficiency of pumped storage power plants, taking into account direct and indirect effects, taking into account the peculiarities of their use in energy and water management systems of Uzbekistan is the main task for the present time. To solve the set tasks, a new methodology and program for substantiating the technical and economic indicators of pumped storage power plants in Uzbekistan's energy and water management systems have been developed. The schemes of using pumped storage power plants at four energy and water management facilities, that is, the Tuyamuyun hydro

* Corresponding author: muhammadiev_m@rambler.ru

subunit, Arnasai, Talimarjan, and Khodjikent reservoirs, were considered, and for these facilities, based on the developed methodology and program, their technical and economic parameters of the pumped storage power plant were determined. Based on the results obtained, it can be said that using the PSPP in four facilities, it is possible to generate a total of about 418 MW of capacity and more than 930.0 million kWh of electricity, as well as to save 139 thousand tons of fuel equivalent per year, with this, the annual economic efficiency will be about 700.0 billion sums.

1 Introduction

At present, the available generating capacity of the electric power system (EPS) of Uzbekistan is 12.9 GW, of which in TPPs - 11 GW or 84.7 percent, in HPPs - 1.85 GW or 14.3 percent, in block stations and isolated stations - more than 0.133 GW or 1 percent.

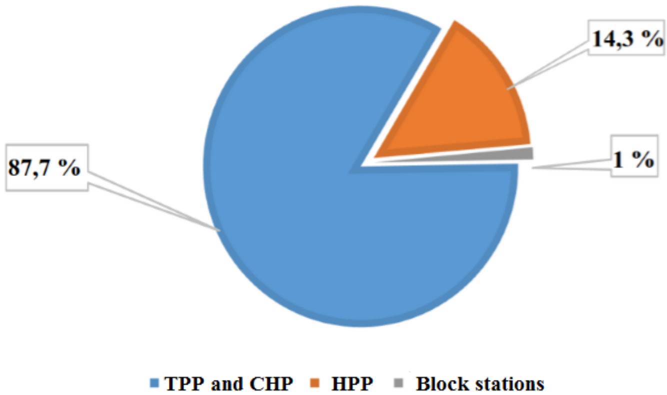

Fig. 1. The structure of electricity generation in the EPS of Uzbekistan

As seen from fig.1, the main source of generation is 11 TPPs, including 3 combined heat and power plants. In 2019, TPPs generated 89.6 percent of the total electricity generated within the Republic. At the same time, the total capacity of power units operating during the hours of maximum loads of the unified EPS was 8.6 GW.

Hydropower includes 42 HPPs, including 12 large ones with a total capacity of 1.68 GW (90.8 percent of the total HPP capacity), 28 SHPPs with a total capacity of 0.25 GW (13.5 percent), and 2 micro HPPs with a total capacity of 0.5 MW. The utilization rate of the Republic's hydro potential is 27 percent.

In Uzbekistan, to achieve the indicators of the development of renewable energy, the target parameters of the annually commissioned capacities of renewable energy sources (RES) in 2020-2030 have been determined, providing for the construction of 3 GW wind and 5 GW solar power plants.

However, along with the positive aspects of the development and saturation of the energy system of Uzbekistan with large power plants of enormous capacity, it aggravates the difficulties in covering the minimum and maximum daily loads of EPS (fig. 2).

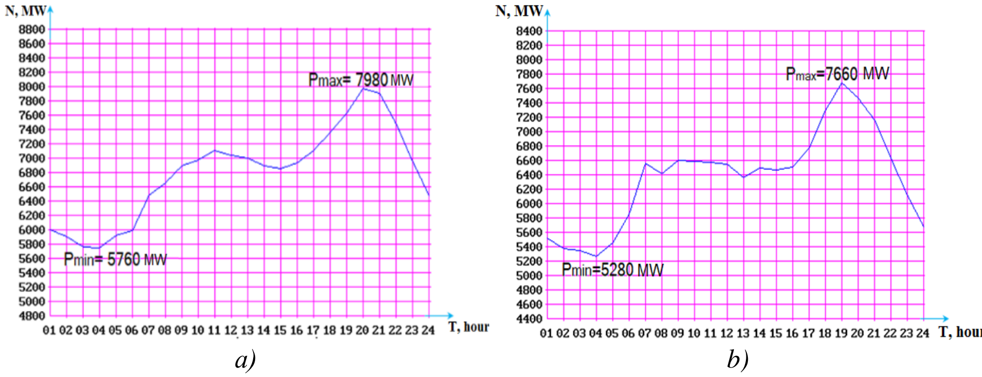

Fig. 2. Diagrams of daily loads of EPS of the Republic of Uzbekistan a) 09.10.2019; b) 15.04.2020.

The limited range of power regulation of large-block units and the impossibility of frequent starts and stops without a sharp decrease in the reliability and efficiency of the operation of the power equipment of thermal power plants, as well as power plants based on renewable energy sources (solar, wind, etc.), which have significant discontinuity even during the day, leads to difficulty covering the uneven part of the electrical load curves and lead to the need to increase maneuverable capacities.

From 2012 to 2019, there was an increase in electricity production at an average of 2.6 percent per year. However, the demand for electric energy was not fully satisfied. The deficit was about 9.4 percent of the demand (figure 3).

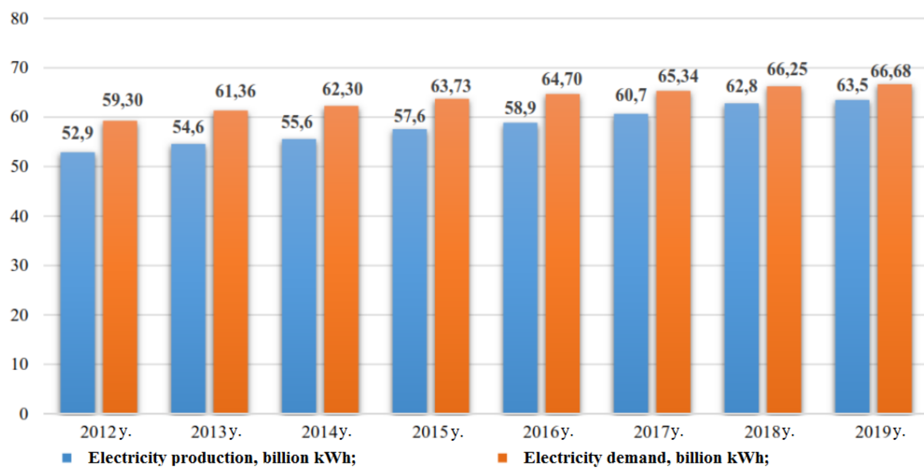

Fig. 3. Factual dynamics of production and demand for electric energy in the period 2012-2019

The maximum load during the peak hours of electricity consumption in winter 2019 was 10.4 GW. The difference between the minimum and maximum load was 2.3 GW. At the same time, in the summer of 2019, the peak indicator reached 9.4 GW with a difference between the minimum load of 2.6 GW (figure 4).

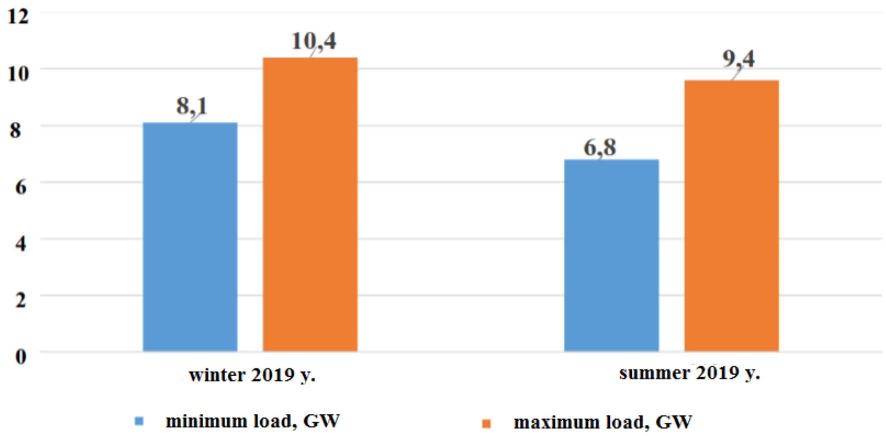

Fig. 4. Minimum and maximum loads for the winter and summer period 2019.

In this direction, special attention in the world is paid to developing new methods for the design, construction, and use of pumped storage power plants (PSPP) and installations that have the best maneuverability compared to other types of maneuverable power plants (HPP, GTU).

For Uzbekistan, it is of particular importance to carrying out research work to improve the maneuverability, reliability, and stability of the EPS with the help of PSPPs, in particular aimed at solving problems, determining the optimal energy-hydraulic and operating parameters, and technical and economic indicators of PSPPs based on increasing their energy, economic and environmental efficiency and taking into account the peculiarities of their use in the energy and water management system (EWMS) of Uzbekistan.

In the economy, methods have now been developed for assessing the economic efficiency of various energy facilities. However, in connection with the increasing urgency of environmental problems, there is a further development of methods for determining power plants' economic efficiency, which allows taking into account environmental issues. In particular, in [15, 21], it was shown that in assessing the efficiency of a PSPP, in addition to its main task - maneuverable capacity, it is also necessary to take into account the possibilities of increasing the reliability and efficiency of existing energy facilities and water management systems, fuel savings, which also contribute to a decrease in greenhouse gas emissions, and improvement in the ecological state of water - an increase in oxygen saturation.

The development of a methodology for determining the economic efficiency of a PSPP, taking into account direct and indirect effects, is the main task in the design of PSPPs for the conditions of Uzbekistan.

2 Methods

For this purpose, a methodology has been developed for determining the economic indicators of a PSPP, which allows solving the higher specified problem and makes it possible to determine - capital investments in PSPP (K_{PSPP}), electricity generation in turbine mode (TM) (E_{TM}), electricity consumption in pumping mode (PM) (E_{PM}), annual savings in fuel resources (D_{fuel}), fuel economy (E_{fuel}), the annual cost of PSPP (I_{PSPP}), economic efficiency per year (E_{PSPP}), payback period ($T_{payback}$) and profitability of capital investments R.

As you know, economic efficiency in the general case is the difference between income and costs. Consider the economic characteristics of the PSPP, taking into account the features mentioned above of its application capital investments in PSPP K_{PSPP} are generally equal:

$$K_{PSPP} = N_{TM} \cdot \alpha_{PSPP}, \text{ [sum]}. \quad (1)$$

where, α_{PSPP} is specific capital investment, sum/kW;
Annual electricity generation in TM E_{TM}:

$$E_{TM} = 365 \cdot t_{TM} \cdot N_{TM}, \text{ [kWh]}, \quad (2)$$

where, *365* is days of the year; t_{TM} is operating time of the PSPP in TM during the day.
Electricity consumption in PM E_{PM}:

$$E_{PM} = 365 \cdot t_{PM} \cdot N_{PM}, \text{ [kWh]}. \quad (3)$$

t_{PM} is operating time of the PSPP in PM during the day.
Savings in foreign currency while reducing the purchase of peak electricity from neighboring power systems $S_{\$}$ [14]:

$$S_{\$} = E_{TM} \cdot \beta_{PM}, \text{ [USD]}. \quad (4)$$

$\beta_{\$}$ *is* cost of 1 kWh of peak electricity in neighboring power systems, USD/kWh.
Cost of 1 kWh of peak electricity in the EPS of Uzbekistan β_{TM} [19, 23]:

$$\beta_{TM} = 1{,}4 \cdot \beta_{E}, \text{ [sum/kWh]}. \quad (5)$$

β_E is electricity tariff in the normal period of the EPS load schedule, sum/kWh;
The cost of 1 kWh of electricity during the load failure period in the EPS β_{PM} [17,22]:

$$\beta_{PM} = 0{,}7 \cdot \beta_{E}, \text{ [sum/kWh]}. \quad (6)$$

The cost of electricity generated by the PSPP during the peak S_{TM} period:

$$S_{PM} = E_{TM} \cdot \beta_{TM}, \text{ [sum]}. \quad (7)$$

The cost of electricity consumed by PSPP in PM S_{PM} occurs during periods of load failure, or:

$$S_{PM} = E_{PM} \cdot \beta_{PM}, \text{ [sum]}. \quad (8)$$

Annual savings in fuel resources D_{fuel}:

$$D_{fuel} = \gamma \cdot E_{PM}, \text{ [kg.c.f]} \quad (9)$$

γ is specific fuel economy per 1 kWh of electricity in the PSPP, kg.c.f./kWh.
Fuel economy E_{fuel}:

$$E_{fuel} = D_{fuel} \cdot \beta_{fuel}, \text{ [sum].} \quad (10)$$

β_{fuel} is cost of 1 kg.c.f, sum/kg.c.f.
Annual costs of PSPP I_{PSPP} [15]:

$$I_{PSPP} = I_{dep} + I_{ser} + I_{wage} + I_{oe}, \text{ [sum].} \quad (11)$$

where I_{dep} is depreciation deductions for PSPP are taken the same as for HPP, or 5% of capital investments for the creation of PSPP K_{PSPP}:

$$I_{dep} = 0{,}05 \cdot K_{PSPP}, \text{ [sum].} \quad (12)$$

I_{ser} are repair costs, 18% of I_{dep}

$$I_{ser} = 0{,}18 \cdot I_{dep} = 0{,}05 \cdot 0{,}18 \cdot K_{PSPP} = 0{,}009 \cdot K_{PSPP}, \text{ [sum].} \quad (13)$$

I_{wage} is salary of service personnel:

$$I_{wage} = \Delta I_{wage} \cdot n_{per}, \text{ [sum],} \quad (14)$$

where n_{per} is number of personnel; ΔI_{wage} is staff salary; I_{oe} are other expenses (overheads):

$$I_{oe} = 0{,}15 \cdot \left(I_{dep} + I_{ser} + I_{wage}\right) = 0{,}15 \cdot \left(0{,}059 \cdot K_{PSPP} + n_{per} \cdot \Delta I_{wage}\right), \text{ [sum].} \quad (15)$$

As a result, for a PSPP with a capacity of more than 100 kW:

$$I_{PSPP} = 0{,}06785 \cdot K_{PSPP} + 1{,}15 \cdot \Delta I_{wage} \cdot n_{per}, \text{ [sum].} \quad (16)$$

For pumped storage power plants with a capacity of less than 100 kW ($I_{oe} = 0$ and $I_{wage} = 0$)

$$I_{PSPP} = 0{,}05 \cdot K_{PSPP} + 0{,}009 \cdot K_{PSPP} = 0{,}059 \cdot K_{PSPP}. \quad (17)$$

And the annual economic efficiency of the PSPP E_{PSPP} will be equal to

$$E_{PSPP} = S_{TM} + E_{fuel} + Ei - I_{PSPP} - S_{PM} - 0{,}15 \cdot K_{PSPP}, \text{ [sum].} \quad (18)$$

where Ei is indirect economic effects, including the effects of reducing greenhouse gas emissions from E_{GG}, improving the operating modes of existing energy facilities (increasing the reliability and efficiency) of the E_{EO} and increasing the reliability of the EPS E_{PS}, or

$$Ei = E_{GG} + E_{EO} + E_{ES}, \text{[sum]} \quad (19)$$

The effect of reducing greenhouse gas emissions due to PSPP is determined through the expression

$$E_{GG} = E \cdot \beta_{CO2}, \text{[sum]} \quad (20)$$

where β_{CO2} are annual costs of environmental measures to remove CO_2 are taken 15 ... 20 $/ton [4,6,20]; E is annual CO_2 emission, for each type of fuel (combustion plants) is produced according to the formula:

$$E = M \cdot K_1 \cdot NCV \cdot K_2 \cdot 44/12, \text{[tons/year]} \quad (21)$$

where M is actual fuel consumption for the year:

$$M=\gamma \cdot E_{PM}, \text{[tons/year]} \quad (22)$$

where K_1 is oxidation factor of carbon in the fuel (shows the fraction of burned carbon), $K_1 = 0.98\text{-}0.995$; NCV is net calorific value, J/ton; K_2 is carbon emission factor, ton/J; 44/12 is coefficient of conversion of carbon into carbon dioxide (molecular weights, respectively: carbon is 12 g/mol, $O_2 = 2 \cdot 16 = 32$ g/mol, $CO_2 = 44$ g/mol).

Determination of the actual fuel consumption is based on the accounting data of the enterprise on the consumption of various types of fuel.

Indirect components of the economic effect of E_{EO} and E_{ES} can be calculated based on data on the characteristics of the operation of existing energy facilities and power systems - efficiency, reliability, stability.

The formulas obtained are general. However, there are some peculiarities when assessing the economic effects for PSPP with less than 100 kW capacity. So, for example, the component of $0.15 \cdot K_{PSPP}$ (other expenses - costs for infrastructure, ecology, etc.) and the indirect effects of E_{EO} and E_{ES} are not taken into account.

Payback period of capital investments $T_{payback}$ at the PSPP will be equal to [16,19]:

$$T_{payback} = \frac{K_{PSPP}}{E_{PSPP}}, \text{[year]} \quad (23)$$

or the return on investment R in the PSPP is [12]:

$$R = \frac{E_{PSPP}}{K_{PSPP}} \quad (24)$$

Based on this methodology, which also takes into account indirect effects, a program was developed [22], which provides determination of the PSPP capacity in TM and PM, the required useful volume of water, the annual electricity generated in the TM, and the consumed electricity for water accumulation in the PM, the efficiency, capital investments for the creation of a PSPP, the cost of the annual generated and consumed electricity, the annual savings of fuel resources and its monetary value, the annual costs of PSPP, the

https://doi.org/10.1051/e3sconf/202126404056

annual economic efficiency from the creation of PSPP, taking into account indirect effects, the payback period of the investment and the profitability ratio.

3 Results and Discussion

Based on the developed methodology and program, the technical and economic indicators of pumped storage power plants were investigated when EWMS used them at the Tuyamuyun hydro subunit, Arnasai, Talimarjan, and Khodjikent reservoirs (Fig. 5), and the results are given in tables 1÷3.

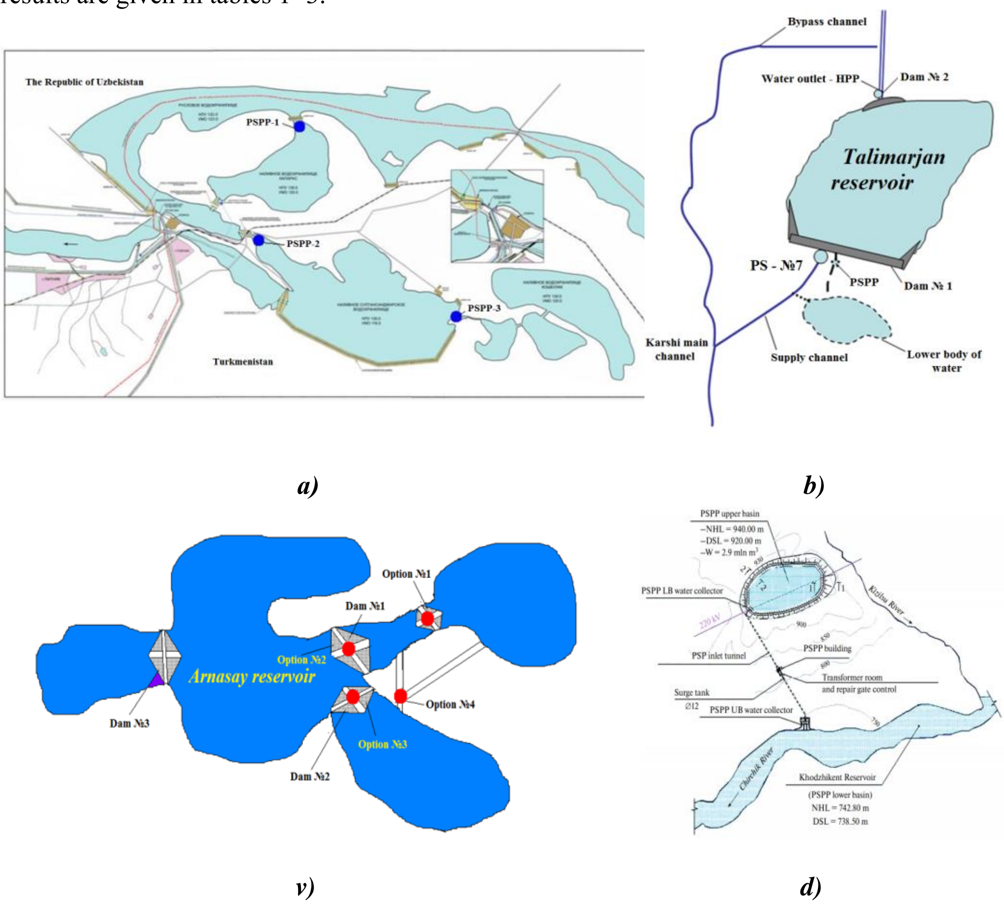

Fig. 5. Schemes of the proposed EWMS using PSPP:

a) scheme of the Tuyamuyun hydro subunit; *b)* scheme of the Talimarjan reservoir;

v) scheme of the Arnasai reservoir; *d)* scheme of the Khodjikent reservoir.

Table 1. Main technical and economic indicators of pumped storage power plants when using them at Tuyamuyun hydro subunit

№	The name of indicators	Unit of measurement	The values of the PSPP at the Tuyamuyun hydro subunit		
			PSPP 1	PSPP 2	PSPP 3
1	Pressure in TM	*m*	7.87	6.7	5.8
2	Pressure in PM	*m*	10.1	9.2	7.7
3	Consumption in TM	m^3/sec	214	234	246
4	Consumption in PM	m^3/sec	170	180	190
5	The volume of water used for accumulation per day	$mln.m^3$	4.62	5.05	5.31
6	Power in TM	*kW*	14 209	13 273	11 939
7	Power in PM	*kW*	19 793	19 180	17 147
8	The efficiency of the PSPP	%	73.19	73.10	73.40
9	Capital investment	*billion. sum*	50.72	47.38	42.62
10	Electricity generation in TM per year	*million. kWh*	31.117	29.068	26.147
11	Annual electricity consumption in PM	*million. kWh*	54.566	54.605	48.620
12	The cost of generated electricity during the peak period per year	*million. sum*	9958.739	9302.910	8368.151
13	The cost of consumed electricity in PM per year	*million. sum*	8731.583	8737.912	7780.146
14	Annual savings in fuel resources	*t.s.f.*	4667.575	4360.194	3922.081
15	Yearly cost	*million. sum*	3453.208	3226.556	2903.506
16	Economic efficiency per year	*million. sum*	9116.314	7933.105	7213.451
17	Payback period of capital investments	*summer*	5.56	5.97	5.91
18	Return on investment	%	0.177	0.165	0.167

Table 2. The main technical and economic indicators of PSPP when using them in the Arnasai reservoir

№	The name of indicators	Unit of measurement	The values of the PSPP at the Arnasai reservoir			
			Option 1	*Option 2*	*Option 3*	Option 4
1	Pressure in TM	*m*	12	9	6	15
2	Pressure in PM	*m*	14.4	10.8	7.2	18
3	Consumption in TM	m^3/sec	440	480	500	420
4	Consumption in PM	m^3/sec	360	390	400	340
5	The volume of water used for accumulation per day	*million. m*^{3}	9.50	10.37	10.80	9.07
6	Power in TM	*kW*	44 545	36 573	25 104	53 620
7	Power in PM	*kW*	59 480	48 554	33 755	69 892
8	The efficiency of the PSPP	%	73.53	73.44	71.40	74.53
9	Capital investment	*billion. sum*	159.02	130.56	89.62	191.42
10	Electricity generation in TM per year	*million. kW·h*	97.554	80.095	54.977	117.428
11	Annual electricity consumption in PM	*million. kW·h*	159.207	130.873	92.404	189.078
12	The cost of generated electricity during the peak period per year	*billion. sum*	31.22	25.63	17.60	37.58
13	The cost of consumed electricity in PM per year	*billion. sum*	25.47	20.94	14.78	30.25
14	Annual savings in fuel resources	*thousand. t.s.f.*	14.633	12.014	8.247	17.614
15	Yearly cost	*billion. sum*	10.80	8.87	6.09	13.00
16	Economic efficiency per year	*billion. sum*	30.53	25.03	16.76	37.16
17	Payback period of capital investments	*summer*	5.21	5.22	5.35	5.15
18	Return on investment	%	18.904	18.883	18.420	19.120

Table 3. Main technical and economic indicators of PSPP when using them in Talimarjan and Khodjikent reservoirs

№	The name of indicators	Unit of measurement	The values of the PSPP at the Talimarjan reservoir	The values of the PSPP at the Khodjikent reservoir
1	Pressure in TM	*m*	24.2	180
2	Pressure in PM	*m*	25.8	194
3	Consumption in TM	m^3/sec	90	130
4	Consumption in PM	m^3/sec	72	104
5	The volume of water used for accumulation per day	$million.\,m^3$	1.94	2.90
6	Power in TM	*kW*	18 473	199 991
7	Power in PM	*kW*	21 314	233 129
8	The efficiency of the PSPP	%	73.92	73.56
9	Capital investment	*billion. sum*	31.0	2839.1
10	Electricity generation in TM per year	*million. kWh*	40.456	452.6
11	Annual electricity consumption in PM	*million. kWh*	58.346	659.5
12	The cost of generated electricity during the peak period per year	*billion. sum*	12.95	158.41
13	The cost of consumed electricity in PM per year	*billion. sum*	9.33	115.41
14	Annual savings in fuel resources	*thousand. t.s.f.*	6.07	67.90
15	Yearly cost	*billion. sum*	2.12	192.65
16	Economic efficiency per year	*billion. sum*	5.44	564.55
17	Payback period of capital investments	*summer*	5.7	5.029
18	Return on investment	%	0.175	0.199

Based on the results given in tables 1 ÷ 3, we can say that:

- the considered PSPP options, differing in the location of PSPP in the Tuyamuyun hydroelectric power station, are almost the same from an economic point of view, which shows the possibility of creating at this hydroelectric facility the interstate use of the hydropotentials of its reservoirs when using PSPP. This will increase the stabilization of the operation modes of the EPS of Turkmenistan and Uzbekistan and receive an additional 86.5 million kWh of environmentally friendly electricity and, accordingly, peak capacities up to 39.4 MW using PSPP with an annual economic efficiency of 24.3 billion soums and fuel economy 12.95 thousand tons of fuel equivalent;
- all options for constructing a pumped storage power plant on the Arnasay reservoir are almost the same from an economic point of view; this also makes it possible to use the hydro potential of the Chardara and Arnasay reservoirs and improve the operating modes of the EPS in Kazakhstan and Uzbekistan. In general, this will make it possible to obtain at least 350.0 million kWh of electricity per year, to create a pumped storage power plant with a total capacity of 159.8 MW with an annual economic efficiency of

109.5 billion sums, including a fuel economy of 52.5 thousand tons of fuel equivalent. t.;

- the capacity of the PSPP at the Talimarjan reservoir can reach 18.473 MW, the annual economic efficiency can be 5.44 billion sums, and the peak electricity generation will be 40.456 million kWh, and the fuel economy will be 6.07 thousand tons of fuel equivalent;
- the capacity of the Khojikent PSPP can be 200 MW with an annual output of 452.600 million kWh of electricity with an annual economic efficiency of 564.55 billion sum, including an annual fuel saving of 67.90 thousand tons of fuel equivalent.

4. Conclusions

1. The state and modes of operation of the EPS of the Republic of Uzbekistan show that to improve the functioning of the EPS, maneuverable capacities are needed, in particular, it indicates that this requires the creation of pumped storage power plants operating in the daily, weekly and seasonal mode of energy storage.
2. At present, the existing reservoirs of the Republic are mainly used for irrigation purposes, partly for drinking water supply. For complete use of the potential of water resources in the operated reservoirs, it is necessary to create hydropower complexes that, in their essence, are capable of solving the issues of electricity production during the depletion of reservoirs.
3. Terrain relief is of great importance in designing a PSPP - desirable to use local reservoirs and elevation differences to increase the pressure and thus improve its economic performance. In our region, it is necessary to take into account the new conditions for the creation of pumped storage power plants - low-pressure, at the same time high capacities, as well as the maximum use of existing reservoirs and watercourses, which are mainly of water economic importance.
4. The developed methodology for substantiating the technical and economic indicators of PSPP in Uzbekistan's energy and water systems and its software implementation can be used in the design and development of a feasibility study at PSPP and determining its optimal options.
5. The technical and economic indicators of the PSPP according to the developed methodology are preliminary; that is, the capacity of the projected PSPP will depend on the possibility of creating sufficient capacities of the upper and lower basins, and the injection and operation modes will be determined by the results of optimization technical and economic calculations for the requirements of the power system, taking into account the long-term strategy its development.

References

1. The concept of providing the Republic of Uzbekistan with electric energy for (2020-2030).
2. Mukhammadiev M.M., Dzhuraev K.S Justification of the energy and economic parameters of pumped storage power plants in Uzbekistan. International journal "Applied Solar Energy", Vol. 56, №3, pp.227-232. (2020).
3. Mukhammadiev M and Klichev Sh Use of Pumped Storage Hydroelectric Power Plants in Uzbekistan. International journal "Applied Solar Energy", Vol. 54, №6, pp.468-471. (2018).

4. Mukhammadiev M, Urishev B Use and accumulation of renewable energy in the energy system of the Republic of Uzbekistan. Monograph, Tashkent, NURFAYZ, p. 252. (2020).
5. Mukhammadiev M, Urishev B, Mamadiyorov E and Dzuraev K Low-power power plants based on renewable energy sources. Monograph, Tashkent TDTU, p. 162. (2015).
6. Muhammadiev M and Urishev B. Hydroaccumulative power plants. Monograph. Publishing house "Fan va texnologiya", Tashkent, p. 212. (2018)
7. Mukhammadiev M, Dzhuraev K and Klychev Sh Capabilities of Hydroelectric Pumped-Storage Stand-Alone Power Plants. International journal "Applied Solar Energy", Vol. 49, №4, pp. 267–271. (2013).
8. Klychev I. Sh., Mukhammadiev M. M., Nizamov O.Kh., Mamadierov E.K., Dzhuraev K.S., Saifiev A.U Method for calculating the power of combined autonomous electric power plants. International journal "Applied Solar Energy", Vol. 50, №3, pp.196-201. (2014).
9. Dzhuraev K., Nasrulin A., Shadibekova F., Kurbonov Sh Geoinformation systems at the selection of engineering infrastructure of pumped storage hydropower for the Tuyamuyun complex. IOP Conference Series: Materials Science and Engineering, Volume 869, Number 4, Engineering Infrastructure, IOP Publishing, pp.1-10
10. Muhammadiev M., Urishev B., Juraev S. and Boliev A 2020 Detritus removal from a pumping-plant intake chamber with hydrajet pumps. IOP Conference Series: Materials Science and Engineering, Volume 883, IOP Publishing, pp.1-8. (2020)
11. Mukhammadiev M, Nasrulin, A Mukolyants A and Ergasheva D A complexly method of GIS technologies and optimization models used in the development of environmentally acceptable modes of operation of hydraulic and hydropower facilities in Uzbekistan. Journal of Physics: Conference Series, Vol.1425. (2020).
12. Barbour E, Wilson I A G, Radcliffe J, Ding Y L and Li Y L A review of pumped hydroenergy storage development in significant international electricity markets Renew Sust Energ Rev, 61, pp. 421-432. (2016).
13. Guittet M, Capezzali M, Gaudard L, Romerio F and Vuille F F Study of the drivers and asset management of pumped-storage power plants historical and geographical perspective Energy 111, pp. 560-579. (2016).
14. Connolly D, Lund H and Mathiesen BV Smart Energy Europe: the technical and economic impact of one potential 100% renewable energy scenario for the European Union Renew Sust Energ Rev, № 60 pp.1634-1653
15. Steffen B Prospects for pumped-hydro storage in Germany 2012 Energ Policy, 45 pp. 420-429. (2016).
16. Zhang S, Andrews-Speed P and Perera P The evolving policy regime for pumped storage hydroelectricity in China: a key support for low-carbon energy Appl Energy, 150 pp. 15-24. (2015).
17. Brandi A A 2014 Pumped storage hydropower: A Technical Review. B.S., University of Colorado, p. 84.
18. Utamuradova Sh.B., Daliev Kh.S., Daliev Sh.K, Fayzullaev K.M. The influence of chromium and iron atoms on the processes of defect formation in silicon. Applied Physics, (6), pp.90-95. (2019).
19. Yang C J (2010). Pumped Hydroelectric Storage: Technical report http://people.duke.edu/-cy42/
20. Denholm P, Ela E Kirby B and Milligan M (2010) The role of energy storage with renewable electricity generation Technical report NREL/TP-6A2-47187

21. Urishev B.U. Increasing the efficiency of use and accumulation of hydraulic energy of renewable sources: abstract of thesis. Doctors of technical sciences: 05.05.06 – p. 73. Tashkent, (2018).
22. Nazari M, Ardehali M and Jafari S Pumped storage unit commitment with considerations for energy demand, economics, and environmental constraints. Energy; 35 (10), pp 4092–101. (2010).
23. Mukhammadiev M M, Dzuraev K S, Zhuraev S R, Kulanov Zh B and Mamatkulov D A The program for determining the energy – economic parameters of pumped storage power plants. Application for certificate of official registration of a computer program №. DGU07363 (2019).
24. M Mukhammadiev, O Glovatskiy, N Nasyrova, N Karimova, A Abduaziz uulu and A Boliev. Assessment of investment technologies for use of hydro – accumulating stations on intermediate channels of irrigation systems and water reservoirs. IOP Conf. Series: Earth and Environmental Science 614 (2020) 012088 doi:10.1088/1755-1315/614/1/012088
25. *Mukhammadiev* M.M, *Urishev* B. U., *Abduaziz uulu* A, *Gadaev* S. K, *Zhankabylov* S.U. Issues of using local energy systems with hydraulic energy storage in the power system of the Republic of Uzbekistan. ICECAE 2020, Tashkent. E3S Web of Conferences 216, 01138 (2020) https://doi.org/10.1051/e3sconf/202021601138