Technical science and innovation

Volume 2023 | Issue 4 Article 6

12-30-2023

USE OF HYDROELECTRIC POWER PLANTS IN REGULATION OF DAILY LOAD OF THE ELECTRIC POWER SYSTEM OF THE REPUBLIC OF UZBEKISTAN

Boborakhim Urishev
Karshi Institute of Engineering and Economics, Karshi city, Republic of Uzbekistan

Burkhon Donayevich Donayev,
Karshi Institute of Engineering and Economics, Karshi city, Republic of Uzbekistan

Recommended Citation
Urishev, Boborakhim and Donayev,, Burkhon Donayevich (2023) "USE OF HYDROELECTRIC POWER PLANTS IN REGULATION OF DAILY LOAD OF THE ELECTRIC POWER SYSTEM OF THE REPUBLIC OF UZBEKISTAN," *Technical science and innovation*: Vol. 2023: Iss. 4, Article 6.
DOI: https://doi.org/10.59048/2181-0400
E-ISSN: 2181-1180
.1539
Available at: https://btstu.researchcommons.org/journal/vol2023/iss4/6

UDC: 621.3

USE OF HYDROELECTRIC POWER PLANTS IN REGULATION OF DAILY LOAD OF THE ELECTRIC POWER SYSTEM OF THE REPUBLIC OF UZBEKISTAN

B.U.URISHEV, B.D.DONAYEV (Karshi Institute of Engineering and Economics, Karshi city, Republic of Uzbekistan)*

Received: December 28, 2023; Accepted: December 30, 2023; Online: January 16, 2024.

Abstract. *The necessity of optimal regulation of power generation and consumption in the energy system of the Republic of Uzbekistan by highly manoeuvrable hydro- and hydro-storage power plants has been substantiated, their participation in the regulation of energy production process has been analysed on the example of the daily load schedule of the energy system. The method of determining the energy characteristics of power plants by solving the problem of optimal distribution of loads between hydro- and thermoelectric power plants during the day, taking into account the maximum use of limited water resources. The results of calculations of load distribution between hydro- and thermoelectric power plants in order to equalise the schedule of energy loads of thermal power plants in the power system with an increase in the non-uniformity coefficient from 0.79 to 0.826, which leads to a decrease in the frequency of alternating modes of operation of thermal power plants and, consequently, to a reduction in fuel consumption during the start-up of units, as well as the accident rate of thermal equipment.*

Key words: *hydroelectric power plant, pumped storage power plant, thermal power plant, water consumption, fuel consumption, daily load schedule.*

Annotatsiya. *O'zbekiston Respublikasi energetika tizimida elektr energiya ishlab chiqarish va iste'mol qilishni yuqori quvvatli gidroelektrostantsiyalar va gidroakkumulyatorlar tomonidan optimal tartibga solish zarurligi asoslab berildi, energiya ishlab chiqarish jarayonini tartibga solishda ularning ishtiroki misolida tahlil qilindi. Energiya tizimining kunlik yuklanish jadvali ishlab chiqildi. Cheklangan suv resurslaridan maksimal darajada foydalanishni hisobga olgan holda, kun davomida gidro- va issiqlik elektr stansiyalari o'rtasida yuklanishlarni optimal taqsimlanish masalasini hal qilish orqali elektr stantsiyalarining energiya xususiyatlarini aniqlash usuli o'rganildi. Elektr tizimidagi issiqlik elektr stansiyalarining energiya yuklanishlari jadvalini tengsizlik koeffitsientining 0,79 dan 0,826 gacha ko'tarilishi bilan tenglashtirish uchun gidroelektr va issiqlik elektr stansiyalari o'rtasida yuklanish taqsimotini hisoblash natijalariga ko'ra yuklanish pasayishiga olib kelishi aniqlandi. Issiqlik elektr stantsiyalarining o'zgaruvchan ish rejimlarining chastotasida va shunga mos ravishda agregatlarni ishga tushirishda yoqilg'i sarfini hamda issiqlik uskunasining avariya darajasi kamayishiga olib kelinishi o'rganilgan.*

Kalit so'zlar: *GES, nasosli elektr stansiyasi, issiqlik elektr stansiyasi, suv sarfi, yoqilg'i sarfi, kunlik yuklanish jadvali.*

Аннотация. *Обоснована необходимость оптимального регулирования производства и потребления электроэнергии в энергетической системе Республики Узбекистан высоко маневренными гидро- и гидроаккумулирующими электростанциями, проанализировано их участие в регулировании процесса производства энергии. Суточный график нагрузки энергосистемы. Метод определения энергетических характеристик электростанций путем решения задачи оптимального распределения нагрузок между гидро -и теплоэлектростанциями в течение суток с учетом максимального использования ограниченных водных ресурсов. Результаты расчетов распределения нагрузки между гидро- и теплоэлектростанциями с целью выравнивания графика энергетических нагрузок тепловых электростанций в энергосистеме с увеличением коэффициента неравномерности с 0,79 до 0,826, что приводит к снижению в частоту смены режимов работы тепловых электростанций и, как следствие, к снижению расхода топлива при пуске агрегатов, а также аварийности теплового оборудования.*

Ключевые слова: *гидроэлектростанция, гидроаккумулирующая электростанция, тепловая электростанция, водопотребление, расход топлива, суточный график нагрузки.*

Introduction

One of the main directions of increasing the efficiency and reliability of the electric power system (EPS) of the Republic of Uzbekistan is the solution of

* Donayev, Burkhon Donayevich – PhD, Professor, https://orcid.org/0000-0002-9142-4671;
Urishev Boborakhim – DSc, Professor, https://orcid.org/0000-0002-9455-150X.

a wide range of operational tasks associated with the need for optimal regulation of the use of electricity production and consumption [1,2,3,4]. These tasks include the following:

- ensuring the reliability of the power system by regulating the daily load schedule, especially in its peak part, voltage and frequency;
- optimisation of thermal power plants (THPSs) operation, improvement of their technical and economic performance, reduction of harmful emissions into the atmosphere by reducing operating modes of power units with variable loads on the basis of rational use of capacities of all types of power plants;
- Ensuring the constant presence of a fast-acting emergency reserve of generating capacity;
- ensuring mutually beneficial electricity transaction with other EESs, including decentralised, local and others [5,6].

Participation of hydroelectric power plants (HEPs) in power regulation in EES is caused by their ability to respond quickly to load changes, which is an important condition for ensuring normal operation of the power system in terms of daily load schedule equalisation. It takes 1...2 min to start up a hydroelectric power unit from the stopped position with synchronisation and power gain until the parameters are fully stabilised [7,8,9].

At THPSs, manoeuvring capabilities are limited. Modern gas turbine units (GTU) require at least 10 minutes to start up a turbine generator from the cold state to operate under rated load, combined cycle gas turbine units (CCGT) - 120...240 minutes [10]. For example, a modern hybrid unit created on the basis of aviation and power gas turbine engines by "General Electric" LMS100 with a gas flow rate of 122 kg/sec at power gain in 10 minutes consumes 73.2 tonnes of fuel [11]. According to the data of the unitary enterprise "Talimarjan THPS" for 2017, the number of stops of the CCGT-2 power unit consisting of one GTU with an installed capacity of 300 MW and two CCGTs with a capacity of 150 MW each, was 7, and the total annual fuel consumption for the start-up of the units was 796 thousand m^3 , which corresponds to an average fuel loss for each start-up of 113.7 thousand m^3 of natural gas [12]. These data indicate that the operation of THPS power units in modes with variable loads is associated with huge fuel costs and their replacement by highly manoeuvrable hydroelectric units of HEPs and SHEPs leads to savings of significant fuel resources.

Specialists of the International Energy Agency believe that hydropower will become a dominant tool in ensuring the flexibility of emergency reserve capacities, rapid regulation of power systems operation [13]. This is confirmed by the events that occurred in February 2021, when a catastrophic situation arose in the U.S. power system of Texas due to the lack of highly manoeuvrable control capacities (primarily, hydropower), and, conversely, in January 2021 in Europe it was possible to avoid collapses in power supply due to the timely use of fast-acting hydropower capacities [14].

Thus, a characteristic feature of modern EPS is an integrated approach to solving the problem, which requires the construction of a single powerful power complex consisting of basic low-maneuverability and high-maneuverability peak, semi-peak sources, controlled by a common dispatching centre, the main task of which is reliable, high-quality power supply with minimum costs while complying with environmental standards.

The analysis of the possibility of using highly manoeuvrable capacities in Uzbekistan shows the insufficiency of the scale of works being carried out in this direction, especially on the construction of hydroelectric power plants.

The unevenness coefficient of the daily load schedule of the EES of the Republic of Uzbekistan in the winter period is 0.72...0.78 (Fig. 1). The experience of foreign energy systems with predominance of THPSs with such irregularity coefficients shows that the share of all highly manoeuvrable plants should be at least 25% of the total installed capacity of the energy system [7].

The capacities of HEPs of the Republic of Uzbekistan are mainly used in the middle and semi-peak parts of the EES schedule on the basis of daily regulation of water flow, which provides for limitation of water flow through HEPs in the periods of minimum and increase - in the maximum semi-peak periods of energy loads. It is known that the degree of participation of HEPs in load schedule regulation can be seriously increased if they have reservoirs, but the share of HEPs with such facilities in the Republic does not exceed 48 % of their total capacity, which means that the regulating capacity of HEPs to cover peak loads is no more than 6...7 % of the capacity of all power plants in the energy system.

In this regard, due to low regulation of watercourses of the Republic, the approximate mode of operation of HEPs in the energy system of the Republic looks as it is shown in Fig. 1.

This graph is based on data from the Ministry of Energy and Uzbekhydroenergo JSC of the Republic of Uzbekistan, which corresponds to the date 18 December 2017.

Daily power generation at HEPs is determined by hourly summation of generation of all HEPs for 18.12.2017 and reflection of the results on the daily schedule of EES for the same date, and the total generation of HEPs was 12,640 thousand kW, which is almost twice less than the average daily generation for 2017. This is explained by the fact that in the winter period the water flow rate in sources decreases and water is accumulated in reservoirs for irrigation needs.

If we take into account the possibilities of operative regulation of HEP capacity for up to 1-2 minutes by changing the water flow rate, all HEPs to some extent can be used in the modes of short-term load changes for capacity regulation, as well as power quality (maintenance of normalised values of frequency and voltage) [7,8,9].

In this regard, the maximum regulating capacity of HEPs does not exceed 12 % of the total installed capacity of all power plants (the total installed capacity of HEPs is 2000 MW and that of all power plants is 16 000 MW) [15,16].

Frequent start-ups and shutdowns of turbine units lead to fuel overconsumption, decrease in durability of heat engineering equipment and increase in repair costs, increase in accidents and time of restoration of normal operation [7].

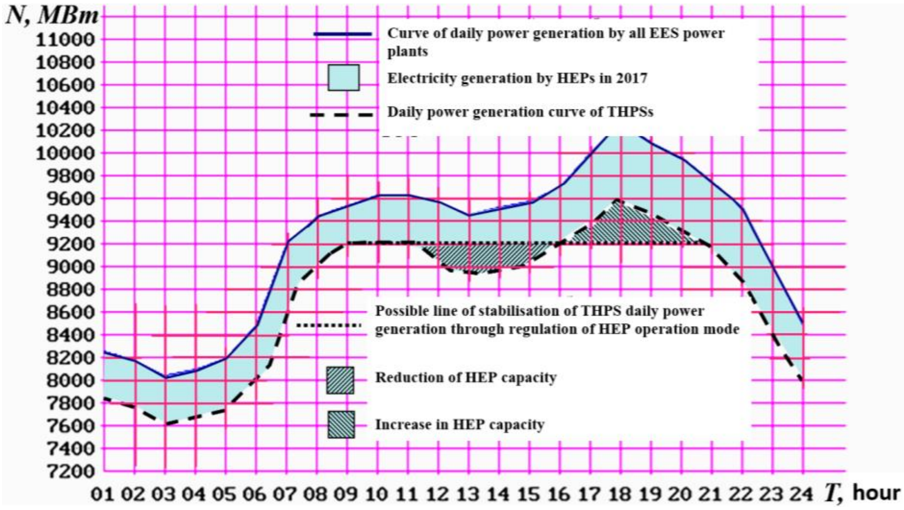

Fig. 1. Daily schedule of the operating mode of EES of the Republic of Uzbekistan for 18.12.2017.

The main cause of accelerated wear of thermal equipment at its frequent and short-term shutdowns is the uneven temperature state of various elements of the turbine, boiler and steam pipelines, which leads to their cooling at different rates [7,8]. According to foreign data, about 25% of emergency shutdowns of thermal equipment occur due to damage during start-up [7].

Thus, due to the variability of daily schedules of energy consumption and water consumption in sources, it is necessary to regulate the capacity of HEPs in the modes of short-term changes in the loads of EES on the basis of specially for this purpose developed programme complexes that provide optimal operation modes of HEPs taking into account changes in water consumption for other purposes.

Methods and materials

The efficiency of the technological process of a hydroelectric power plant, first of all, depends on the optimal utilisation of energy resources and management of the operating mode of hydroelectric units.

For the available values of resources in a certain time interval, there is such a mode of operation of HEP, which has minimum energy losses, maximum efficiency and provides generation of as much electricity as was calculated with the available water resources. This mode of HEP operation is optimal, and it fulfils the following criteria

$$Э_{HEP} = \int_0^{t_T} N_{HEP}(t) \cdot dt \to max, \qquad (1)$$

$$\eta_{HEP} \to max, \qquad (2)$$

where $Э_{HEP}, N_{HEP}$ - value of energy generated by HEP during operation time t_T and corresponding power;

η_{HEP} *is the* efficiency factor of the HEP.

Let us consider the optimisation problem of daily operation mode *i = 1, 2..., n of* HEP together with THPS. In this case, we consider that the head of HEP varies little, i.e., H ≈ const, losses in transmission lines and distribution network are neglected, and the daily load graph *P(t) is* represented by a continuous function. As is known, under such conditions, the main constraints are the conditions of capacity balance in the power system and fixed water volumes in watercourses.

Water volume limitation

$$V_i - \sum_{t=1}^{k} Q_{\text{HEP}it} \cdot \Delta\tau_t = 0; \qquad (3)$$

where V_i is the volume supplied by each HEP; Q_{HEPit} is the water flow rate of the *i-th* HEP for time *t*, lasting $\Delta\tau$, *t* = 1, 2,..., *k*.

Capacity balance conditions in a power system:

for $t = 1$

$$P(1) - \sum_{i=1}^{n} N_{\text{HEPi}}(1) - N_{\text{THPS}}(1) = 0 \quad (4)$$

for $t = k$

$$P(\text{к}) - \sum_{i=1}^{n} N_{\text{HEPi}}(\text{к}) - N_{\text{THPS}}(\text{к}) = 0$$

where $P(t)$ is the value of daily load at time t, $N_{ТЭС}(t)$ is the capacity of THPS at time t.

The target function in the form of a Lagrangian function characterising the most favourable load distribution between HEPs and THPSs, which would ensure minimum fuel equivalent consumption in the system taking into account (3) and (4) is as follows

$$L = (B_1 + B_2 + \ldots + B_k) + \lambda_1 \cdot P_1 + \ldots \lambda_2 \cdot P_2 + \ldots + \lambda_k \cdot P_k + \lambda_1 \cdot V_1 + + \lambda_2 \cdot V_2 + \ldots + \lambda_n \cdot V_n \quad (5)$$

where λ_1, λ_k,..., λ_n *are* uncertain Lagrange multipliers; B is the conditional fuel consumption.

Taking the partial derivatives of N_{THPSt1}, N_{HEPt2}, ..., $N_{HEPtk\ n}$, equating them to zero and solving the obtained expressions, we obtain the optimality conditions.

$$\frac{\partial B(t_1)}{\partial N_{\text{THPS}}(t_1)} = \frac{\partial B(t_2)}{\partial N_{\text{THPS}}(t_2)} = \ldots = \frac{\partial B(t_k)}{\partial N_{\text{THPS}}(t_k)} = \ldots = \lambda_1 \frac{\partial Q_{\text{HEP1}}(t_1)}{\partial N_{\text{HEP1}}(t_1)} = \ldots = \lambda_2 \frac{\partial Q_{\text{HEP2}}(t_2)}{\partial N_{\text{HEP2}}(t_2)} = \ldots = \lambda_i \frac{\partial Q_{HEPn}(t_k)}{\partial N_{\text{HEPn}}(t_k)} \quad (6)$$

Let us analyse the possibility of obtaining a solution to the target function equation (5). The number of unknowns in this equation is equal to: power of THPS in each time interval k, power of n HEP in each time interval t, total $k + n$. Lagrange multipliers λ are also unknown: n - multipliers λ, total unknowns $k + 2 \cdot n$.

Number of equations: k - from optimality conditions, n - power balance equations, n - water volume balance equations, (total $k + 2 \cdot n$. Thus, the number of equations and the number of unknowns are equal and the conditions for solving the equation are sufficient.

Taking the following abbreviations $\partial B(t)/\partial N_{THPS}(t) = b(t)$ and $\partial Q(t)/N_{HEP}(t) = q(t)$ *to* equation (6*)* let us write in the following form:

$$b(t_1) = b(t_2) = \ldots b(t_k) = \ldots = \lambda_1 \cdot q_{HEPi}(t_1) = \ldots = \lambda_2 \cdot q_{HEPi}(t_2) = \ldots = \lambda_n \cdot q_{HEPn}(t_k) \quad (7)$$

where $b(t_1) = b(t_2) = \ldots b(t_k)$ - relative fuel increments under THPS capacity change; $q_{HEPi}(t_1)$,... $q_{HEPn}(t_k)$- relative water consumption increments under HEP capacity change.

All values of equation (6), except for Lagrange multipliers, are determined by the energy characteristics of the equipment [$N_{THPS} = f(b)$, $N = f(Q)$] using them it is possible to determine the multipliers λ_i, which mean the fuel efficiency[3] of 1 m of water. The multipliers λ_i are selected in such a way that the calculated total water consumption in the HEP, determined on the basis of limited water volumes in water sources according to condition (3), is ensured.

The most favourable regime will be such if $\lambda = const$ for all HEPs during the whole optimization period.

For example, in case of operation of HEPs with different capacity values, the best variant will be the operation of THPS with the capacity $N_{THPS} = const$, corresponding to the optimal fuel consumption for it and ensuring compliance with conditions (3) and (4) (Fig. 2).

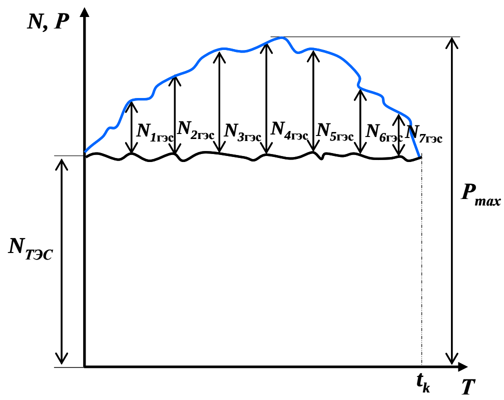

Fig. 2. - Distribution of loads between HEPs and THPSs

Distribution of loads between HEPs and THPSs is carried out by calculation of parameters specified in (7) within time $t_1 \ldots t_k$ (Table 1).

Table 1

Determination of optimal load distribution of HEPs and THPSs

t	P_i	Q_{HEPi}	N_{HEPi}	N_{THPS}	b	λ
t_1 t_2 $t_к$	P_1 P_1 P_k	Q_{HEP1} Q_{HEP1} $Q_{HEP\ k}$	N_{HEP1} N_{HEP2} $N_{HEP\ k}$	$N_{HEP} = P_i - N_{HEPi}$	$b = const_{onm}$	$\lambda = const$

Possible values of water flow rate used for energy generation in HEP in time intervals $t...t_k$ are determined based on the constraint in (3).

The values of total HEP capacity are determined at fixed constant values of head H and HEP efficiency $\eta_{ГЭС}$ by the formula

$$N_{HEPi} = 9.81 \cdot H - Q_{HEPi}\, \eta_{HEPi} \qquad (8)$$

THPS capacity is calculated depending on the values of daily loads and HEP capacity

$$N_{THPSi} = \sum_{t=1}^{k}(P_t - N_{HEPt}) \qquad (9)$$

In this case, by regulating the flow rate of water passing through the HEP within the constraint (3), approximately equal values of N_{THPS} in the intervals $t...t_k$ are achieved, which determine the optimal fuel consumption B and allow to take its value $b = const$

The multiplier λ *is* determined by the following relationship $\lambda = v\text{-}\ N_{HEPi}\ /\ Q_{HEPi}$, and they have approximately the same values, i.e. $\lambda = const.$

As an illustration, Fig. 3 shows the energy characteristics N_{HEPi} - Q_{HEPi} and N_{THPSi} - B plotted based on the values of Q_{HEPi} and B.

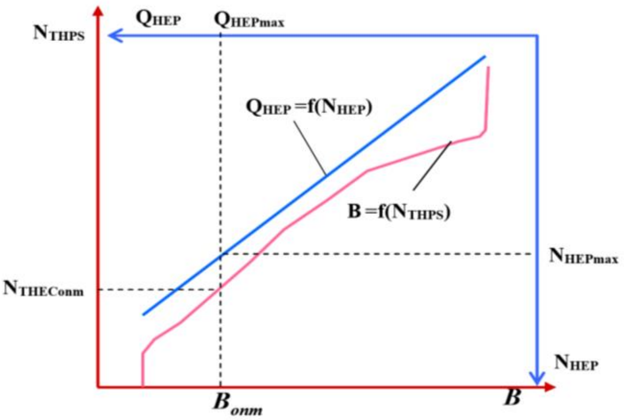

Fig.3. Energy characteristics of N_{HEPi} – Q_{HEPi} and N_{THPSi} – B

The maximum HEP capacity corresponds to the THPS capacity for which the optimal fuel consumption is characterised by B_{onm}, since at this point it will be minimal due to the maximum utilisation of the HEP capacity.

Results and Discussion

Let's consider what will be the benefits of equalising the schedule of daily power generation of THPS by substituting part of the capacity with the help of HEP on the example of the schedule shown in Fig.1. To stabilise the THPS power generation, it is proposed to carry out additional regulation of the HEP operation mode, which provides for the following mode of operation of the power system. In the period from 09^{00} to 21^{00} THPSs operate with stable capacity of 9200 MW, for which the capacity of HEPs from 11^{00} to 16^{00} is reduced by maximum 250 MW, thus creating the condition for preservation of the appropriate volume of water in reservoirs (Charvak, Andijan, Tupalang, Gisarak and Ahangaran). At the same time, the electricity generated by the HEP is reduced by 600 MW·h (it is determined, for example, by the graph shown in Fig.1).

Approximate value of this water volume is determined by the known dependence V= $E_Г$ ·367/H ·η_{HEP} = 600·367/90·0,8 = 3000 thousand m^3 . In this case, H is the average water head in the above reservoirs, $\eta_Г$ is the average value of HEP efficiency. The value of $E_Г$ is determined by the graph in Fig. 4. in the time interval from 11^{00} to 16^{00}. Further, starting from 16^{00} to 21^{00} the accumulated volume of water is supplied to the hydroelectric units of the HEP, increasing their total capacity to a maximum of 400 MW (total 1100 MW) in 18^{00} hours, which makes it possible to additionally generate E = V·H· η_{HEP} /367 =3000·90·0,8/367 = 588 MW·hour electricity.

An increase in volume by 3000 thousand m^3 for 5 hours on the operation of the above reservoirs with a total volume of 5.0 billion m^3 should have no appreciable effect, and the resulting total installed capacity of the hydropower plants during the peak hour of about 1100 MW is about 55 % of the total installed hydropower capacity.

As can be seen from the graph, such distribution of HEP capacity ensures the THPS operation mode without changes in the time interval from 09^{00} to 21^{00}. At the same time, the non-uniformity coefficient increases from 0.79 to 0.826, which leads to a significant stabilisation of the power generation process due to the exclusion of variable modes of THPS operation, leading to a reduction in fuel consumption during unit start-ups and accidents of heating equipment.

Conclusion

1. The analysis of HPS operation in the EES of the Republic of Uzbekistan has shown that the majority of HPSs cannot actively participate in the process of regulating the schedule of the EES of the Republic, as they are low-pressure riverbeds, have no regulating reservoirs and operate only according to the regime of the watercourse. In this connection, due to low regulation of watercourses of the Republic, the degree of participation of HPS in regulation of EPS capacity in peak parts of load schedules does not exceed 6...7 %.

2. To increase the degree of participation of HEPs in the regulation of the daily load schedule in its peak parts, on the example of one of the load schedules of the energy system, it is proposed to redistribute the capacity of HEPs, by accumulating 3000 thousand m^3 of water in reservoirs with the subsequent use of this volume to cover peak loads, which allows to significantly equalise the schedule of

capacity utilisation of THPSs with a change in the unevenness coefficient from 0.79 to 0.826.

3. To determine the energy characteristics of HEPs, the method of solving the optimisation problem of the daily mode of their operation together with THPSs was used, which allows to determine the distribution of loads between HEPs and THPSs, allowing a minimum of fuel equivalent consumption with available water resources.

Acknowledgements

The work was carried out with the financial support of the Ministry of Innovative Development of the Republic of Uzbekistan under the project F3-OT-2021-235 "Theoretical bases of hydropower development using hydropower complexes".

References

1. Resolution of the President of the Republic of Uzbekistan PP-44 "On additional measures for further development of hydropower" dated 10.12. 2021. http://lex.uz.
2. Energy Efficiency 2020. https://www.iea.org/reports/energy-efficiency-2020.
3. Hydro Equipment Association global technology roadmap. https://www.andritz.com/resource/blob/259432/5487f2c45ab370859ffe8abc26ed72e8/ea-roadmap-data.pdf.
4. Yu. S. Vasilyev, V. V. Elistratov, I. G. Kudryasheva, M. Mukhammadiyev, Urishev B. Use of maneuverable properties of hydroelectric power plants and hydro-accumulating power plants for improving reliability and operating efficiency of electric power systems of commonwealth countries (using example of power plants of russia and the Republic of Uzbekistan). E3S Web of Conferences 216, 01139 (2020), RSES 2020. https://doi.org/10.1051/e3sconf/202021601139
5. Urishev B Microgrid Control Based on the Use and Storage of Renewable Energy Sources. USA, Journal Applied Solar Energy, 2018, Vol. 54, No. 5, pp. 388-391. DOI: 10.3103/S0003701X180 50201
6. Urishev B Decentralised Energy Systems, Based on Renewable Energy Sources. USA, Journal Applied Solar Energy, 2019, Vol. 55, No. 3, pp. 207-212. DOI: 10.3103/S0003701X19030101
7. Sinyugin V.Yu., Magruk V.I., Rodionov V.G. Hydro-storage power plants in modern electric power engineering/ - M. : ENAS, 2008.- 352 p.
8. Zubarev V.V. Accumulating power stations and their use in power systems. -M.: "Informenergo", ser.4, issue 4, 1986.p.34-38
9. Zubakin V.A. It is necessary to develop highly manoeuvrable capacities// Energorynok. 2004. № 9. с. 34-42.
10. Hydropower Special Market Report. Analysis and forecast to 2030. https://iea.blob.core.windows.net/assets/83ff8935-62dd-4150-80a8-c5001b740e21/Hydropower SpecialMarketReport.pdf
11. Energy. Development of thermal power and hydropower (Book 3). History, present and future. Edited by Plachkova S.G., Plachkov. I.V. http://energetika.in.ua/ru/books/book-3/part-2/section-3/3-1;
12. Report of production and technical activities of UE "Talimarjan THPS" for 2017. Nuristan, 2017, 37 p.
13. Hydropower Status Report 2022. Sector trends and insights. https://assets-global.website-files.com/5f749e4b9399c80b5e421384/62c402eb2af8db8431332d62 IHA-2022-Hydropower-Status-Report.pdf
14. Hydropower Status Report 2021. Sector trends and insights. https://assets-global.websiteiles.com/5f749e4b9399c80b5e421384/60c37321987070812596e26a_IHA2021_2405-status-report-02LR.pdf
15. Uzbekhydroenergo JSC. https://uzgidro.uz
16. Ministry of Energy of the Republic of Uzbekistan. https://minenergy.uz

UDC 621.314.223

EXISTING METHODS FOR MONITORING POWER AUTOTRANSFORMERS

N.B.PIRMATOV, D.R.ABDULLABEKOVA (Tashkent State Technical University, Tashkent city, Republic of Uzbekistan)*

Received: November 08, 2023; Accepted: January 10, 2024; Online: January 16, 2024.

Abstract: *This paper presents a review of existing methods for monitoring power autotransformers in power systems. With the growing importance of reliable operation of power equipment, analyzing effective methods is becoming an integral part of ensuring power system stability.*

The paper reviews traditional approaches including temperature, pressure, and current monitoring. These methods undoubtedly have their value, but the focus is on innovative techniques.

* Nurali Berdiyorovich Pirmatov – DSc, Professor, npirmatov@mail.ru, https://orcid.org/0000-0001-5212-2593;
Dilafruz Rustamjon qizi Abdullabekova – Doctoral student, abdullabekova_94@mail.ru, https://orcid.org/0009-0003-8887-6831.