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Improving the reliability of urban electrical distribution networks based on optimal configuration

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Improving the reliability of urban electrical distribution networks based on optimal configuration

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Abstract. This paper presents a comprehensive study of the issues related to providing continuous and reliable power supply to electricity consumers connected to urban distribution networks. Within the scope of the research, methods for forming an optimal configuration aimed at improving the reliability of consumers power supply have been developed. These methods are proposed taking into account the structure of urban electrical distribution networks, load characteristics, and existing technical constraints. In addition, the application of the optimal configuration makes it possible to reduce power supply interruptions, enhance network stability, and improve the quality indicators of electrical energy delivered to consumers. The obtained results are recommended for practical application in the design and modernization of urban power supply systems.

INTRODUCTION

At present, ensuring the continuity and reliability of electricity consumption is one of the priority tasks of the electric power industry in developed cities around the world. Therefore, measures aimed at improving the technical and economic performance of power supply systems are being increasingly implemented on a large scale. Under conditions of population growth, urban infrastructure expansion, and rising demand for electrical energy, the efficient operation of urban electrical distribution networks becomes particularly important. In this context, the formation of an optimal network configuration is considered one of the key factors ensuring the stability and economic efficiency of the power supply system [1, 5, 14, 19].

The optimal configuration of urban electrical distribution networks is formed based on the results of optimal analysis conducted with respect to the ideal structure of such networks. During this analysis, the developed principles and optimal construction algorithms determine the placement of network elements, their interconnections, and the distribution of power flows. As a result, technical losses occurring during the transmission and distribution of electrical energy are reduced, and the overall reliability level of the network is enhanced [2, 4, 6, 18].

From a practical point of view, when designing urban electrical distribution networks, a number of key parameters are determined in advance. These include the cross-sectional areas of medium-voltage and low-voltage (up to 1000 V) network cables, the rated capacities of transformer substations (TS), as well as the number of outgoing feeders from the supply source. For areas with the same electrical load density, these parameters remain almost constant and are taken as initial conditions when selecting the network configuration [1, 8, 11].

Under such conditions, the optimal configuration of distribution electrical networks must satisfy several important requirements. First of all, the total length of the network and the lengths of lines at each rated voltage level should be minimized. This allows construction and operational costs to be reduced. At the same time, the optimal configuration should correspond to the minimum total capital and operating costs. Economically rational placement of network elements contributes to reducing the cost of electrical energy and increasing investment efficiency [3, 6, 9].

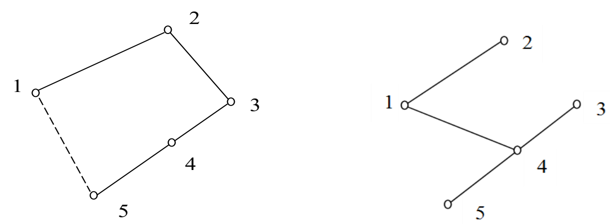
If, at a given voltage level, the optimal load of each line is approximately the same, such a condition ensures a balanced distribution of loads throughout the network. As a result, overloading of lines and transformers is prevented, the probability of emergency situations is reduced, and the overall reliability indicators of the network are improved. Therefore, the formation of an optimal configuration is an effective means of minimizing the total costs of urban electrical distribution networks and achieving uninterrupted power supply to electricity consumers [1-2, 17].

EXPERIMENTAL RESEARCH

At the initial stage of forming an optimal configuration of an urban electrical distribution network, the construction of a basic configuration “element” is considered. This element represents a fundamental structural unit of the network and is defined by a set of fixed points in a two-dimensional plane corresponding to electricity consumption nodes. These points are assumed to be preliminarily grouped and spatially separated in accordance with the load distribution and urban layout characteristics [3, 11, 15]. The methodological basis of this stage relies on classical graph-theoretical approaches for connecting a finite number of fixed nodes under given constraints.

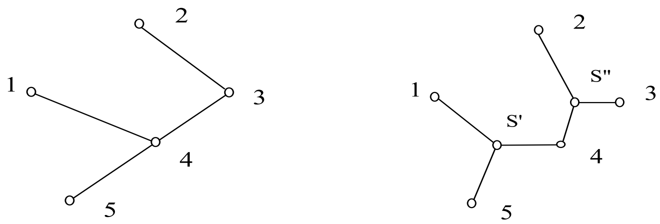
Existing methods for determining the optimal configuration of urban power distribution networks generally approximate the solution by constructing minimum spanning trees or minimum-cost tree structures, sometimes supplemented by auxiliary connections [4, 7]. Any problem related to the determination of an optimal network configuration can be reduced to one of several canonical topological models, depending on the admissible connection rules and node characteristics. In this context, the following cases must be considered [10]:

- if connections are allowed only between adjacent points, and each node can be connected by no more than two edges, the problem corresponds to a single linear connection path, as illustrated in Figure 1a;
- if arbitrary connections between points are permitted and each node can serve as a branching point for two or more edges, the problem is classified as [10] a minimum spanning tree problem (Figure 1c);
- if additional edges may be connected at existing nodes without introducing new branching points, the configuration corresponds to a shortest-distance tree, where distances are minimized relative to a reference node (Figure 1b);
- if the introduction of additional branching nodes (not belonging to the original set of *N* marked points) is allowed, the configuration [20] corresponds to a Shteiner tree construction (Figure 1d).



a) “One-line connection” path (open)

b) The tree of the shortest distances compared to the initial peak (1)



c) Minimum tree

d) Shteiner tree: S', S" - additional peaks

FIGURE 1. Possible topological models for network configuration based on the spatial distribution of consumption nodes.

These theoretical models provide a useful framework for understanding the structural properties of optimal configurations. However, their practical applicability depends strongly on the physical, technical, and regulatory constraints inherent to urban environments [7, 13, 18, 20].

When selecting an optimal configuration for urban distribution networks, particular attention must be paid to the routing characteristics of cable lines. In practice, low-voltage cable lines (up to 1000 V) are typically laid within landscaped areas, along pedestrian pathways, or beneath lawns, while medium-voltage cable lines are predominantly installed under sidewalks or along roadways. These routing constraints impose a rectilinear structure on cable paths, which significantly affects distance calculations [4, 6, 9, 12-45].

Analysis of existing urban distribution networks and implemented design projects shows that, for cable routing in city environments, the use of rectilinear (Manhattan) distance provides a more realistic estimate of cable length than conventional Euclidean distance [20]. Accordingly, the distance between two points in the plane is expressed as:

$$d = |X_1 - X_2| + |Y_1 - Y_2|, \quad (1)$$

where, in this case, the coordinate of points X_1, Y_1, X_2, Y_2 - 1 and 2. It should be noted that, under this metric, multiple routes of equal minimum length may exist between two points, reflecting the flexibility of cable routing along orthogonal urban corridors [17].

From a purely theoretical perspective, the construction of a Shteiner tree can yield a substantial reduction in total line length-up to approximately two-thirds compared to a minimum spanning tree. However, the practical implementation of Shteiner tree solutions in urban cable networks is limited by several critical factors:

- additional branching nodes introduced by Shteiner constructions often lack the capability to accommodate multiple cable connections at consumer access points, particularly where three or four feeders converge. This limitation adversely affects both economic feasibility and power supply reliability [15];
- urban environments impose numerous physical and regulatory restrictions on cable routing, including existing underground infrastructure, land ownership boundaries, and safety requirements, which restrict the placement of additional branching nodes.

As a result, despite their theoretical attractiveness, Shteiner tree principles are generally unsuitable for the formation of cable line configurations in urban distribution electrical networks.

In contrast, in small cities and rural areas, overhead distribution lines with rated voltages of 0.4, 6 or 10 kV are widely used. Under these conditions, the formation of minimum tree structures with additional branching nodes can be both technically feasible and economically justified [16]. This is due to two primary factors:

- first, the creation of additional branching points on overhead line supports is relatively inexpensive and can be implemented in a straightforward and reliable manner;
- second, small cities typically exhibit lower building density and larger spacing between consumers, resulting in a higher number of consumers being connected to a single feeder. In such cases, the introduction of additional branching nodes can significantly reduce the total length of distribution lines and improve network efficiency [3].

The above considerations define the construction of a configuration “element” with *N* consumption points distributed in a plane. The complete problem of determining the optimal configuration of an urban distribution electrical network-under previously selected optimal parameters that remain invariant for approximately uniform load density - can be formulated as follows [11, 14, 19-20].

Given *N* consumption points with known spatial coordinates and calculated electrical loads, it is required to determine:

- the optimal location and rated capacity of transformer substations;
- the configuration of all low-voltage (≤1000 V) distribution lines supplied by each transformer substation;
- the configuration of the medium-voltage distribution network serving the considered area [3].

All network lines must be selected with optimal current-carrying capacity and must satisfy technical, operational, and topological constraints, including those related to routing bandwidth and urban infrastructure limitations [5, 7, 14]. The fundamental procedures for constructing the optimal configuration of an electrical distribution network with *N* fixed nodes in the plane are thus established, forming the basis for further computational optimization and reliability analysis.

RESEARCH RESULTS

Based on previously selected optimal techno-economic parameters, the problem of forming an optimal configuration of urban distribution electrical networks requires a complex, multi-stage computational procedure [8, 14, 18]. This procedure is aimed at ensuring reliable, cost-effective, and efficient delivery of electrical energy to consumers and is implemented through the following sequential steps:

a) consumer grouping and placement of transformer substations: at the initial stage, electricity consumers within the urban area are grouped according to transformer substations (TS) with optimal rated capacity. The grouping process takes into account the magnitude of consumer loads, their spatial coordinates, and consumption characteristics. For each group, the electrical load center is determined, and the optimal location of the corresponding transformer substation is identified based on this center [2, 5]. As a result, the number of TS, their rated capacities, and their spatial distribution are technically and economically justified.

b) design of the low-voltage network (≤1000 V) within each TS service area: in the next stage, a low-voltage distribution network with a rated voltage of up to 1000 V is designed within the service area of each transformer substation [4]. During this process, the optimal current-carrying capacity of outgoing feeders is selected. The loads supplied by each outgoing feeder are divided into subgroups, and feeder routing is determined in accordance with the spatial distribution and magnitude of the connected loads. As a result, the geometric configuration, length, and load allocation of each feeder are established.

c) iterative refinement of low-voltage network configuration: to improve the efficiency of the low-voltage network, the initial consumer grouping assumptions are revised. Within this iterative procedure, the locations of transformer substations, their service areas, and the configuration of the ≤1000 V network are recalculated [1]. The iteration process continues until the selected optimization criteria-such as minimization of total network length, reduction of power losses, or minimization of construction costs - are satisfactorily met.

d) grouping of transformer substations for the medium voltage network: after forming the low-voltage networks, transformer substations are grouped for connection to the medium-voltage distribution network [3] (typically 6–10 kV). The set of TS supplied by each medium-voltage feeder is determined, and the optimal current-carrying capacity of these feeders is selected. Subsequently, the layout and configuration of each feeder branch are defined.

e) iterative optimization of the medium-voltage network configuration: at the final stage, the medium-voltage network is optimized through iterative modification of the initial grouping conditions and starting points. Multiple network configuration alternatives are evaluated, and for each alternative, the total length of the medium-voltage network is calculated [6]. The configuration that achieves the minimum total network length is selected as the optimal solution. Where necessary, additional constraints related to network reliability, redundancy, and operational requirements are incorporated into the optimization process.

CONCLUSIONS

This study addressed the problem of improving the reliability of urban electrical distribution networks through the formation of an optimal network configuration based on previously selected techno-economic parameters. A systematic, multi-stage methodology was developed that integrates consumer grouping, optimal placement of transformer substations, and iterative optimization of both low-voltage and medium-voltage network structures.

The proposed approach enables the rational allocation of electrical loads and the efficient spatial organization of network elements while satisfying technical, topological, and operational constraints. By applying iterative refinement at different voltage levels, the methodology ensures balanced load distribution, reduced total network length, and minimized power losses. As a result, the probability of overload conditions and emergency situations is significantly reduced, leading to improved reliability and continuity of power supply for urban consumers.

The analysis of network configuration elements demonstrated that, under realistic urban planning constraints, the use of rectilinear distance metrics provides a more accurate representation of cable routing in city environments than conventional Euclidean distances. While theoretical solutions such as Steiner tree constructions offer potential reductions in line length, their practical implementation in urban cable networks is limited due to reliability, construction, and routing constraints. The proposed configuration principles therefore represent a technically feasible and economically justified compromise between theoretical optimality and real-world applicability.

The obtained results confirm that the formation of an optimal configuration, under conditions of approximately uniform load density, leads to a reduction in capital and operating costs while simultaneously enhancing network reliability and energy supply quality. The developed methodology can be effectively applied in the planning, reconstruction, and modernization of urban distribution networks, particularly in rapidly developing cities with increasing electrical load demand.

Future research will focus on extending the proposed approach by incorporating reliability indices, probabilistic load variations, and distributed energy resources, as well as integrating smart grid technologies and real-time monitoring data to further enhance the resilience and adaptability of urban electrical distribution systems.

REFERENCES

1. Melikuziev M.V. Prospects for the introduction of intellectual systems in city electric networks // AIP Conference Proceedings 2552. 2023. PP, 050021, 1-6. https://doi.org/10.1063/5.0112395
2. Melikuziev M.V., Usmonaliev S., Khudoyberdiev N., Sodikov J., Imomaliev Z. Issues of the design procedure for the power supply system // AIP Conference Proceedings 3152. 2024, 040031. https://doi.org/10.1063/5.0218873
3. Melikuziev M.V., Fayzrakhmanova Z., Akhmedov A., Kasimova G. Development of an Educational Simulator's Working Logic for the Course 'Fundamentals of Power Supply' // AIP Conference Proceedings 3152. 2024, 050025. https://doi.org/10.1063/5.0218875
4. Rasulov A.N., Usmonov E.G., Melikuziev M.V. Transformer-resonant circuit for battery charging // AIP Conference Proceedings 2552. 2023. 050018. https://doi.org/10.1063/5.0111530
5. L.Jing; J.Guo; T.Feng; L.Han; Z.Zhou and M.Melikuziev. Research on Energy Optimization Scheduling Methods for Systems with Multiple Microgrids in Urban Areas. 2024 IEEE 4th International Conference on Digital Twins and Parallel Intelligence (DTPI), Wuhan, China, 2024, pp. 706-711, https://doi:10.1109/DTPI61353.2024.10778839
6. Melikuziev M.V., Nematov L.A., Novikov A.N., Baymuratov K.K. Technical and economic analysis of parameters of city distribution electric network up to 1000 V. E3S Web of Conferences 289, 07016 (2021). https://doi.org/10.1051/e3sconf/202128907016
7. Taslimov A.D., Berdishev A.S., Rakhimov F.M., Melikuziev M.V. Method of choosing the unification of cable sections of electric network cables under conditions of load development uncertainty. E3S Web Conf. 139, 2019. https://doi.org/10.1051/e3sconf/201913901081
8. Taslimov A.D., Berdishev A.S., Rakhimov F.M., Melikuziev M.V. Method of selecting parameters of cable lines distributive networks 10 kV in uncertainty conditions. E3S Web Conf. 139, 2019. https://doi.org/10.1051/e3sconf/201913901082
9. Taslimov A.D., Melikuziev M.V., Najimova A.M., Alimov A.A. Economic load intervals for selection of cable sections for agricultural purpose. E3S Web of Conferences 216, 01159 (2020). https://doi.org/10.1051/e3sconf/202021601159
10. Melikuziev M.V. Determination of the service area and location of transformer substations in the city power supply system. E3S Web of Conferences 384, 01033 (2023). https://doi.org/10.1051/e3sconf/202338401033
11. Civanlar, S.; Grainger, J.J.; Yin, H.; Lee, S.S.H. Distribution Feeder Reconfiguration for Loss Reduction. IEEE Transactions on Power Delivery, 3(3), 2008, pp. 1217–1223.
12. Kader, K.A.; Mannan, M.A.; Hazari, M.R. The Distribution Network Loss Minimization by Incorporating DG Using PSO Technique. AJSE, Vol. 23(3), 2024. https://ajse.aiub.edu/index.php/ajse/article/view/780
13. Krstic, N.N.; Tasic, D.S.; Klimenta, D.O.; Milovanovic, M.J. Improving the Operation of a Distribution Network by Optimal Siting and Sizing of Photovoltaic-Battery Energy Storage Systems. Elektronika ir Elektrotechnika, 30(5), 2024.
14. M'dioud, M.; Bannari, R.; Elkafazi, I. A novel PSO algorithm for DG insertion problem. Energy Systems, 2022 (published 2024). https://doi.org/10.1007/s12667-022-00546-z
15. Baran, M.E.; Wu, F.F. Network Reconfiguration in Distribution Systems for Loss Reduction and Load Balancing. IEEE Transactions on Power Delivery, 4(2), 2019, pp. 1401–1407.
16. Khenissi, I.; Alkhateeb, N.; Sellami, R.; et al. A soft computing technique based on PSO for optimal allocation and placement of PVDG-BES units. Int. J. of Advanced and Applied Sciences, 10(8), 2023.
17. Shirmohammadi, D.; Hong, H.W. Reconfiguration of Electric Distribution Networks for Resistive Line Losses Reduction. IEEE Transactions on Power Delivery, 4(2), 2009, pp. 1492–1498. https://doi.org/10.1109/61.25637.
18. Gnanendar, R.; Sushama, M. Enhancing Distribution Network Efficiency and Symmetry via Optimal Sizing and Location of PV DG Using PSO. IJISAE, 2024.

19. Tsai, L.H. Network Reconfiguration to Enhance Reliability of Electric Distribution Systems. Electric Power Systems Research, 27(2), 2023, pp. 135–140.
20. Zhang, P.; Li, W.; Wang, S. Reliability-Oriented Distribution Network Reconfiguration Considering Uncertainties of Data by Interval Analysis. International Journal of Electrical Power & Energy Systems, 34(1), 2012, pp. 138–144. https://doi.org/10.1016/j.ijepes.2011.08.026.
21. Mahmutkhonov S., Baizhonova L., Mustayev R., Tashmatova S. Dynamic analysis of voltage-ampere characteristics and harmonic distortions in electric arc furnaces. // *AIP Conference Proceedings*. 3331(1), 2025. pp. 070023, 1–5. https://doi.org/10.1063/5.0305745.
22. Bobojanov M., Mahmutkhonov S. Influence of the consumer to power quality at the point of connection // E3S Web of Conferences 384. 2023. PP, 01041, 1-5. https://doi.org/10.1051/e3sconf/202338401041.
23. Reymov K.M., Makhmuthonov S.K., Turmanova G., Uzaqbaev Q. Optimization of electric networks modes under conditions of partial uncertainty of initial information // E3S Web of Conferences 289, 07023 (2021). -2021, pp: 1-4, https://doi.org/10.1051/e3sconf/202128907023.
24. Alimov, U.K., Reimov, A.M., Namazov, Sh.S., Beglov, B.M. The insoluble part of phosphorus fertilizers, obtained by processing of phosphorites of central kyzylkum with partially ammoniated extraction phosphoric acid. Russian Journal of Applied Chemistry. Russ J Appl Chem (2010) 83(3): 545–552. https://doi.org/10.1134/S107042721030328
25. Reymov, A.M., Namazov, S.S., Beglov, B.M. Effect of phosphate additives on physical-chemical properties of ammonium nitrate. Journal of Chemical Technology and Metallurgy 2013 48(4), 391-395. http://dl.uctm.edu/journal/
26. Urishev, B., Fakhriddin Nosirov, and N. Ruzikulova. 2023. “Hydraulic Energy Storage of Wind Power Plants.” E3S Web of Conferences, 383. https://doi.org/10.1051/e3sconf/202338304052
27. Urishev, B., S. Eshev, Fakhriddin Nosirov, and U. Kuvatov. 2024. “A Device for Reducing the Siltation of the Front Chamber of the Pumping Station in Irrigation Systems.” E3S Web of Conferences, 274. https://doi.org/10.1051/e3sconf/202127403001
28. Turabdjanov, S., Sh. Dungboyev, Fakhriddin Nosirov, A. Juraev, and I. Karabaev. 2021. “Application of a Two-Axle Synchronous Generator Excitations in Small Hydropower Engineering and Wind Power Plants.” AIP Conference Proceedings. https://doi.org/10.1063/5.0130649
29. L.Jing, J.Guo, T.Feng, L.Han, Z.Zhou and M.Melikuziev, "Research on Energy Optimization Scheduling Methods for Systems with Multiple Microgrids in Urban Areas," 2024 IEEE 4th International Conference on Digital Twins and Parallel Intelligence (DTPI), Wuhan, China, 2024, pp. 706-711, https://ieeexplore.ieee.org/abstract/document/10778839
30. Baratov, B.N., Umarov, F.Y., Toshov, Z.H. Tricone drill bit performance evaluation. Gornyi Zhurnal, Moscow, 2021. - № 12. - PP. 60-63. DOI:10.17580/gzh.2021.12.11.
31. Toshov, J.B., Toshov, B.R., Baratov, B.N., Haqberdiyev, A.L. Designing new generation drill bits with optimal axial eccentricity | Вопросы проектирования буровых долот нового поколения с оптимальным межосевым эксцентриситетом // Mining Informational and Analytical Bulletin, 2022, (9). - PP. 133–142. DOI: 10.25018/0236_1493_2022_9_0_133
32. Toshov J., Makhmudov A., Kurbonov O., Arzikulov G., Makhmudova G. Development and Substantiation of Energy-Saving Methods for Controlling the Modes of Operation of Centrifugal Pumping Units in Complicated Operating Conditions. Proceedings of the 11th International Conference on Applied Innovations in IT, (ICAIIT), November 2023, Koethen, Germany. – PP. 161-165.
33. J.B. Toshov, K.T. Sherov, B.N. Absadykov, R.U. Djuraev, M.R. Sikhimbayev, Efficiency of drilling wells with air purge based on the use of a vortex tube. NEWS of the National Academy of Sciences of the Republic of Kazakhstan “Series of geology and technical sciences”. – Almaty, Volume 4, Number 460 (2023), 225–235. https://doi.org/10.32014/2023.2518-170X.331
Toshov J., Toshov B., Bainazov U., Elemonov M. Application of Cycle-Flow Technology in Coal Mines. Proceedings of the 11th International Conference on Applied Innovations in IT, (ICAIIT), March 2023, Koethen, Germany. – PP. 279-284.
34. Usmanov, E., Kholikhmatov, B., Rikhsitillaev, B., Nimatov, K. Device for reducing asymmetry // E3s Web of Conferences 461. 2023. PP, 01052, 1-5. https://doi.org/10.1051/e3sconf/202346101052
35. Toshov B., Toshov J., Akhmedova L., Baratov B. The new design scheme of drilling rock cutting tools, working in rotation mode pairs. E3S Web of Conferences 383, 04069 (2023) TT21C-2023 https://doi.org/10.1051/e3sconf/202338304069
36. J.B. Toshev, M.B. Norkulov, A.A. Urazimbetova and L.G. Toshniyozov. Optimization of scheme of placing cutting structures on the cone drill bit. E3S Web of Conf., Volume 402, 10039 (2023), International Scientific Siberian Transport Forum - TransSiberia 2023, https://doi.org/10.1051/e3sconf/202340210039

37. Toshov J., Baratov B., Sherov K., Mussayev M., Baymirzaev B., Esirkepov A., Ismailov G., Abdugaliyeva G., Burieva J. Ways to Optimize the Kinetic Parameters of Tricone Drill Bits. Material and Mechanical Engineering Technology, №1, 2024, 35-45. https://doi.org/10.52209/2706-977X_2024_1_35
38. K.T. Sherov, N.Zh. Karsakova, B.N. Absadykov, J.B. Toshov, M.R. Sikhimbayev, Studying the effect of the boring bar amplitude-frequency characteristics on the accuracy of machining a large-sized part. NEWS of the National Academy of Sciences of the Republic of Kazakhstan “SERIES OF GEOLOGY AND TECHNICAL SCIENCES”. – Almaty, Volume 2, Number 464 (2024), 217–227. https://doi.org/10.32014/2024.2518-170X.405
39. J. Toshov, L. Atakulov, G. Arzikulov, U. Baynazov, Modeling of optimal operating conditions of cyclic-flow technologies with a belt conveyor at coal mine under the "ANSYS" program. AIP Conf. Proc. 3152, 020006 (2024) / III International Scientific and Technical Conference “Actual issues of Power supply systems” (ICAIPSS2023), 7–8 September 2023, Tashkent, Uzbekistan. https://doi.org/10.1063/5.0218904
40. Kholikhmatov B.B., Samiev Sh.S., Erejepov M.T., Nematov L.A. Modelling of laboratory work in the science "Fundamentals of power supply" using an educational simulator based on a programmed logic controller // E3S Web of Conferences 384. 2023. PP, 01032, 1-3. https://doi.org/10.1051/e3sconf/202338401032
41. Rakhimov F, Rakhimov F, Samiev Sh, Abdukhalilov D. Justification of Technical and Economic Effectiveness of Application of 20 kV Voltage in Overhead Electric Networks //AIP Conf. Proc. 3152, 030023 (2024). https://doi.org/10.1063/5.0218921
42. Taslimov A, Mo'minov V, Samiev Sh, Abdukhalilov D. Issues of Optimization of Electrical Network Parameters Medium Voltage //AIP Conf. Proc. 3331, 020007 (2025). https://doi.org/10.1063/5.0305781
43. Toshbekov, O., Urazov, M., Yermatov, S., & Khamraeva, M. 2023). Yeffisient and yesonomisal yenergy use teshnology in the prosessing of domestis soarse wool fiber. In Ye3S Web of Sonferenses (Vol. 461, p. 01068). https://doi.org/10.1051/e3sconf/202346101068
44. Jumaniyozov, K., Urozov, M., Toshbekov, O., Salimova, M., Raximova, K., & Khursandova, B. (2025, November). Enhancement of energy-efficient cleaning equipment. In American Institute of Physics Conference Series (Vol. 3331, No. 1, p. 050007). https://doi.org/10.1063/5.0307149
45. Sultonova, F., Toshbekov, O., Urozov, M., Boymurova, N., Mustanova, Z., & Boltaeva, I. (2025, November). Enhancing and evaluating the characteristics of specialized workwear for employees in the electric power supply sector. In American Institute of Physics Conference Series (Vol. 3331, No. 1, p. 050006). https://doi.org/10.1063/5.0306350