Experimental investigation of the resistance relay in power line protection

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Abstract. The article presents the results of an experimental study to determine the principle of operation, characteristics and effectiveness of a resistance relay used to protect power transmission lines from emergency situations. During the research, the parameters of the current and voltage applied to the relay were changed, and their effect on relay sensitivity, speed, and selectivity was studied. The relay operating modes were also modeled on the basis of a laboratory stand, which creates conditions close to real operating conditions. The results showed that the resistive relay provides high reliability for the rapid detection and localization of short circuits in power transmission lines. This allows you to optimize the sensitivity parameters and angular characteristics of the resistive relay.

INTRODUCTION

Uninterrupted and reliable power supply to consumers is one of the most important requirements of the modern energy system. Accidents on power transmission lines – short circuits, overloads, overvoltages, insulation failures and other technical malfunctions – pose a serious threat to the stability of the system. Therefore, the correct choice and effective operation of relay protection and automation devices in electrical networks are of great importance.

Relay protection is one of the main safety elements of electric power systems, providing emergency detection, rapid isolation of damaged areas and restoration of normal network operation [1-9]. Relay protection is one of them, a resistance relay, used to detect short circuits in power transmission lines and has high selectivity, the principle of operation of which is based on the ratio of current and voltage [10].

In recent years, the complexity of electrical networks, increasing loads and the widespread use of automated control systems have further increased the need for in-depth study and improvement of the technical characteristics of relay protection devices. In this regard, the experimental study of the behavior, sensitivity, accuracy and speed of resistance relays in various operating modes is an urgent scientific and practical task [11-18].

This paper analyzes the role of resistance relays in protecting power transmission lines, the factors affecting their operation, as well as the results of experiments conducted in the laboratory. The research results allow us to draw scientifically sound conclusions on optimizing relay parameters and improving the reliability of protection systems [19-25].

EXPERIMENTAL RESEARCH

In complex power supply circuits, depending on the operating modes and the type of short circuit, the sensitivity of simple current protection may be insufficient. In addition, in some cases, protection may require high performance and high selectivity. In such cases, remote protection is widely used [26-30].

The main advantages of remote protection are: 1) the absence of influence of the operating modes of the power supply system; 2) the short shutdown time of the short circuit, depending on the distance to the damaged area and a number of other factors [31].

At the location of the remote protection devices, the relay reacts by changing the ratio of voltage and current. This value is called the resistance connected to the relay. Therefore, the main starting element of the remote protection is a resistance relay. In this laboratory work, a model of a resistance relay of the KRS-1 types (KRS-1), which is part of the EPZ-1636 panel complex, was studied. Functionally, the model consists of three single-phase resistance relays KZ1, KZ2 and KZ3. The current and voltage at the input of each relay are provided by measuring current and voltage transformers. Since the typical circuit for switching on a resistance relay involves switching on the mains voltage and the phase current difference, the relay has two current coils I1 and I2. The magnetic flux produced by these coils is equal to the difference in the magnetic fluxes produced by each coil individually. The relay is triggered if the value of the complex resistance connected to the relay terminals is less than the setpoint of the relay [31].

Basic relay settings:

$Z_{t.s.min}$ – minimum resistance setting (setpoint), Ohms/phase. It takes one of two values: 1 ohm or 1.5 ohm.

N% is the percentage ratio of the minimum setpoint of the $Z_{t.s.min}$ resistance relay to the calculated setpoint of $Z_{t.s}$.

The position of the two control elements in the device is determined as follows: 1) Rough adjustment: 1%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%; 2) Stepless adjustment: 0...10%. The resulting N% value is determined by summing the values of the three control elements.

ε is the compression ratio of the circular operating characteristic of the relay.

The coefficient is used to obtain an elliptical characteristic. It takes the following values: 0.5; 0.65; 0.8; 1.

Shift is the displacement of the operating characteristic of the relay to the third quadrant. It takes one of two possible values: yes or no. In the presence of a shift, the operating characteristic of the relay is shifted by 10% to the third quadrant from the operating resistance set for the relay.

$\varphi_{max.sen}$ - is the maximum sensitivity angle of the relay. It takes one of two possible values: 65° or 80°.

The operating characteristic of the resistance relay is as follows:

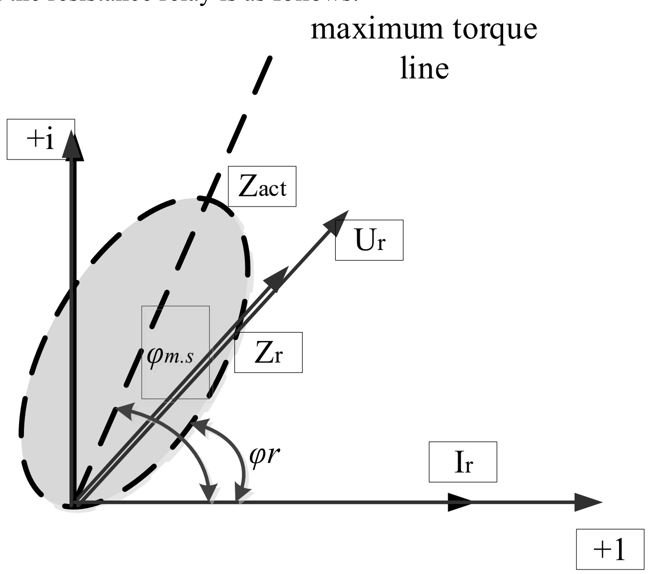

FIGURE 1. Operating characteristics of the resistance relay

The current vector coincides in the direction with the real axis of the complex plane, and the voltage vector is assumed to carry current at a certain angle φ_r (active-inductive load). In this case, the impedance vector Z_r is combined with the voltage vector U_r and its value is determined by the expression U_r/I_r, where current and voltage can be amplitude or effective values. The operating characteristic of the Z_{act} relay has the form of an ellipse (see Fig. 2). The relay is triggered if the complex resistance vector connected to the relay terminals is located inside the dotted part of the ellipse.

These are the operating conditions of the relay in a complex form.

$$Z_r \leq Z_{act} \tag{1}$$

The above relay settings allow you to change the size of the ellipse, the degree of its compression and the angle of inclination.

The main characteristics of the resistance relay are:

- *$Z=f(f_r)$,* which is the dependence of the resistance value of the relay on the angle between the current and voltage applied to the relay windings. At rated current, the division is removed, and the resistance value is determined by the voltage applied to the relay winding.

➢ $Z=f(I_r)$, which expresses the dependence of the value of the relay resistance on the value of the current applied to the relay coils. When the angle between current and voltage is equal to the angle of maximum sensitivity, this dependence disappears, and the resistance value is determined by the values of voltage and current applied to the relay coils.

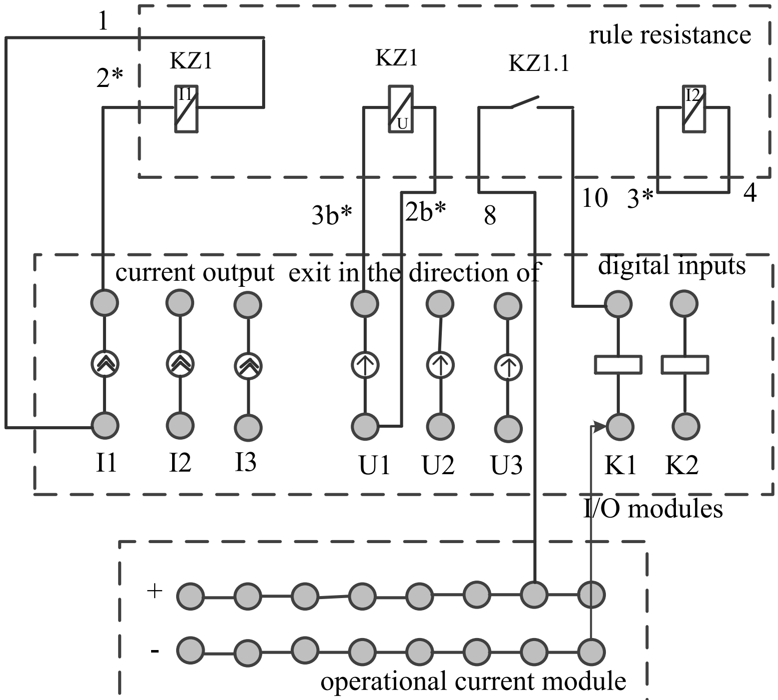

FIGURE 2. Circuit diagram of the resistance relay.

Here we get the values using the automatic program mode when removing the angular response characteristics of the resistance relay.

TABLE 1. Measurement of the operating characteristics of the resistance relay in the form of $Z=f\,(f_r)$.

№	I_r, A	U_{act}, V	φ_r,	$Z_{r.act}$, ohms
1	5.00	0.80	10	0.16
2	5.00	9.90	20	0.98
3	5.00	14.40	30	2.88
4	5.00	19.90	40	3.98
5	5.00	27.30	50	5.46
6	5.00	35.70	60	7.14
7	5.00	44.80	70	8.96
8	5.00	48.60	80	9.72
9	5.00	48.60	90	9.72
10	5.00	43.70	100	8.74
11	5.00	36.80	110	7.36
12	5.00	27.30	120	5.46
13	5.00	20.00	130	4.00
14	5.00	13.80	140	2.76
15	5.00	8.20	150	1.64
16	5.00	4.20	160	0.84
17	5.00	3.10	170	0.62
18	5.00	2.60	180	0.52

The principle of operation, methods of adjusting the settings and the main characteristics of the resistance relay type KRS-1 (KRS-1), shown in Figure 2, were studied.

1. To obtain the dependence $Z = f(f_r)$ (angular characteristics of the relay) using the regulators "Control of current and voltage sources" of the relay, the following nominal values were set:

- the rated current in the coil is 5 A;
- rated voltage — 100 V;
- voltage change time — 2 s;
- the phase angle between current and voltage is from 0° to 180°.

After setting these values, the rated voltage was restored, and the phase shift angle between current and voltage was increased to 10°. The tests were repeated in the same order for different angle values, and the voltage values at which the relay operates for each phase shift angle were recorded in a table [32-61].

After obtaining the angular response characteristics of the resistance relay, based on the results obtained, we plot the resistance dependence.

RESEARCH RESULTS

Based on the test and measurement results, the angular characteristic of the operating relay was constructed in the form of $Z_{ish}=f(\varphi_r)$. The points on the graph correspond to the response characteristics of the resistance relay. The axes of the graph are usually as follows:

- X-axis: Reactance X (Ohms)
- Y-Axis: Active resistance R (Ohms)

The total impedance of an object (for example, a line) in this space is calculated using the formula $Z = r + jx$.

To determine the angular response characteristics of the KRS-1 resistance relay, the angle φ varied from 0° to 180° in 10° increments at a constant current of $I_r = 5$ A. For each angle value, the minimum voltage U_{act} at which the relay was triggered was measured, and the operating resistance was calculated accordingly using the following formula:

$$Z_{act} = \frac{U_{act}}{I_r} \quad (2)$$

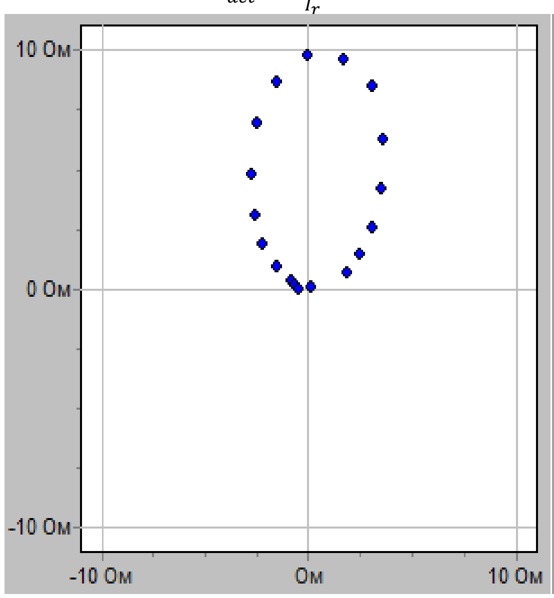

FIGURE 3. Results and performance characteristics obtained using the resistance relay test program

Table 1 shows that the value of the complex resistance increases slowly around the zero angle with increasing φ, increases sharply in the range of 40-60 ° and reaches a maximum value in the range φ = 80-90 °. Then, starting from 90°, Z starts decreasing again. This phenomenon is explained by a classical physical process in relay operation – an inductive voltage lag relative to current.

The highest value determined experimentally:

$$Z_{act}^{max} = 9.72\,\Omega;\ \varphi = 80°–90° \quad (3)$$

This fully complies with the technical specifications specified for the theoretical maximum sensitivity angle φm = 80°.

The Z values measured during the experiment were in the following ranges:

- Minimum value: 0.16 ohms (φ = 10°)
- Maximum value: 9.72 ohms (φ = 80-90°)
- Average value: 4.84 ohms
- Standard deviation: 3.12 ohms

These statistics prove that the angular sensitivity is not linear, but rather sharply variable (nonlinear).

- At small angles φ, the load is predominantly active → Z is also small.
- At angles φ ≈ 80-90°, the inductive component → Z prevails and reaches a maximum.
- At angles φ > 100°, the voltage delay increases, the system approaches the reverse power flow → Z decreases.

This condition plays an important role in the selective operation of remote protection.

The Z–φ curve is not a parabola or a sinusoid, but a selectively increasing and then decreasing curve confirming the elliptical R–X spatial characteristic of the relay response zone.

The difference between the theoretical and experimental values, δ = 3% – 7%, is considered satisfactory accuracy for electromechanical relays.

CONCLUSIONS

In this paper, the principle of operation, angular characteristics and practical significance of the settings of the resistance relay type KRS-1, used to protect power transmission lines, are experimentally investigated. During the tests, the phase shift angle of the current and voltage applied to the relay was changed from 0° to 180°, the relay trip voltage was determined at each angle value and an angular characteristic of the type Z=f(φr) was based on it. The obtained characteristic showed that the operation of the resistance relay significantly depends on the phase shift angle, and also that the maximum sensitivity is observed in a certain angular range. Laboratory experiments have confirmed that the ellipsoid shape of the working area of the KRS-1 relay fully corresponds to the theoretical model. It was found that the settings – minimum resistance, compression ratio, shift function and maximum sensitivity angle – directly affect the selectivity and accuracy of the relay. The test results showed that the optimally tuned relay detects short circuits with high accuracy, has high performance and effectively isolates the damaged area without disrupting the normal operation of the network. The obtained scientific and practical results are important for optimizing the parameters of resistance relays, increasing the accuracy and stability of remote protection devices, and ensuring reliable operation of power transmission lines. The research method can also be used in the evaluation and calibration of other models used in the field of relay protection.

REFERENCES

1. S. Amirov and A. Ataullayev, "Sine-cosine rotating transformers in zenith angle converters," *E3S Web of Conferences* **525**, 03010 (2024). https://doi.org/10.1051/e3sconf/202452503010
2. S. F. Amirov, N. O. Ataullayev, A. O. Ataullayev, B. Q. Muxammadov, and A. U. Majidov, "Methods for reducing the temperature components of magnetomodulation DC convertors errors," *E3S Web of Conferences* **417**, 03011 (2023). https://doi.org/10.1051/e3sconf/202341703011
3. A. Tovboyev, I. Togayev, I. Uzoqov, and G. Nodirov, "Use of reactive power sources in improving the quality of electricity," *E3S Web of Conferences* **417**, 03001 (2023). https://doi.org/10.1051/e3sconf/202341703001
4. I. Togayev, A. Tovbaev, and G. Nodirov, "Assessment of the quality of electricity by applying reactive power sources," *E3S Web of Conferences* **525**, 03004 (2024). https://doi.org/10.1051/e3sconf/202452503004
5. G. Boynazarov, A. Tovbaev, and U. Usarov, "Methodology of experimental research of voltage quality in electrical circuit," *E3S Web of Conferences* **548**, 03009 (2024). https://doi.org/10.1051/e3sconf/202454803009
6. N. Ataullayev, A. Norqulov, B. Muxammadov, A. Majidov, and I. Tog'ayev, "Principles of protection against single phase earth faults in networks with capacitive current compensation," *E3S Web of Conferences* **548**, 06008 (2024). https://doi.org/10.1051/e3sconf/202454806008
7. Z. I. Jumayev, A. I. Karshibayev, M. K. Sayidov, and S. G. Shirinov, "Analysis of climate-meteorological and technological factors affecting electricity consumption of mining enterprises," *Vibroengineering Procedia* **54**, 293–299 (2024). https://doi.org/10.21595/vp.2024.24047
8. A. Tovbaev, M. Ibadullayev, and M. Davronova, "Study of subharmonic oscillation processes in ferroresonance circuits," *E3S Web of Conferences* **525**, 03008 (2024). https://doi.org/10.1051/e3sconf/202452503008

9. B. S. Narzullayev and M. A. Eshmirzaev, "Causes of the appearance of current waves in high voltage electric arc furnaces, and methods of their reduction," *E3S Web of Conferences* **417**, 03003 (2023). https://doi.org/10.1051/e3sconf/202341703003
10. A. Tovbaev, I. Togaev, U. Usarov, and G. Nodirov, "Reactive power compensation helps maintain a stable voltage profile across the network," *AIP Conference Proceedings* **3331**, 060014 (2025). https://doi.org/10.1063/5.0307209
11. A. Norqulov and F. Raximov, "Methods for evaluating financial and economic effectiveness of investment projects in the energy sector with time factor considerations," *AIP Conference Proceedings* **3331**, 030070 (2025). https://doi.org/10.1063/5.0306104
12. S. Abdullaev, Z. Eshmurodov, and I. Togaev, "A systematic analysis of the gradual increase in quality indicators of electricity using reactive power sources involves several steps," *AIP Conference Proceedings* **3331**, 040051 (2025). https://doi.org/10.1063/5.0306786
13. S. F. Amirov, A. O. Ataullayev, M. K. Sayidov, and I. B. Togayev, "Methods of reduction of interference signals in electromagnetic conductors that measure fluid flow," *Journal of Physics: Conference Series* **2094**(5), 052053 (2021). https://doi.org/10.1088/1742-6596/2094/5/052053
14. J. Olimov, B. Ramazonov, and S. Sayfiyev, "Increasing efficiency of induction motor by predictive control system," *E3S Web of Conferences* **525**, 03006 (2024). https://doi.org/10.1051/e3sconf/202452503006
15. K. Murodov and A. Karshibayev, "Development of the management system of technical indications of high-power charger-discharger rectifier device," *E3S Web of Conferences* **417**, 03012 (2023). https://doi.org/10.1051/e3sconf/202341703012
16. G. Tatkeyeva *et al.*, "Experimental research of the developed method to determine the network insulation for ungrounded AC systems in laboratory conditions," in *2022 International Conference on Electrical, Computer and Energy Technologies (ICECET)*, IEEE, 1–4 (2022). https://doi.org/10.1109/ICECET55527.2022.9873012
17. M. Rabatuly, S. A. Myrzathan, J. B. Toshov, J. Nasimov, and A. Khamzaev, "Views on drilling effectiveness and sampling estimation for solid ore minerals," *Comprehensive utilization of mineral raw materials* **1**(336) (2026). https://doi.org/10.31643/2026/6445.01
18. J. B. Toshov, M. Rabatuly, Sh. Khaydarov, A. A. Kenetayeva, A. Khamzayev, M. Usmonov, and A. T. Zheldikbayeva, "Methods for analysis and improvement of dynamic loads on the steel wire rope holding the boom of steel wire rope excavators," *Complex Use of Mineral Resources* **339**(4), 87–96 (2026). https://doi.org/10.31643/2026/6445.43
19. O. U. Zokhidov, O. O. Khoshimov, and Sh. Sh. Khalilov, "Experimental analysis of microHPP installation for existing water flows in industrial plants," *E3S Web of Conferences* **463**, 02023 (2023). https://doi.org/10.1051/e3sconf/202346302023
20. N. Niyozov, A. Akhmedov, S. Djurayev, B. Tukhtamishev, and A. Norqulov, "Development of a method for forecasting the specific consumption indicator of electric energy," *AIP Conference Proceedings* **3331**, 080008 (2025). https://doi.org/10.1063/5.0305729
21. J. Boboqulov and B. Narzullayev, "Development of a model for diagnosing rotor conditions in the parallel connection of synchronous generators with the network," *E3S Web of Conferences* **525**, 06001 (2024). https://doi.org/10.1051/e3sconf/202452506001
22. A. Tursunova *et al.*, "Researching localization of vertical axis wind generators," *E3S Web of Conferences* **417**, 03005 (2023). https://doi.org/10.1051/e3sconf/202341703005
23. B. Ramazonov, S. Sayfiev, and K. Muradov, "Mathematical modeling and research of high capacity lead-acid stabilized accumulator battery," *AIP Conference Proceedings* **3268**, 020043 (2025). https://doi.org/10.1063/5.0257860
24. K. Murodov, A. Karshibayev, and S. Abdullayev, "Analysis of the process of balanced charging of the battery group with high capacity," *E3S Web of Conferences* **548**, 03012 (2024). https://doi.org/10.1051/e3sconf/202454803012
25. M. Xolmurodov, S. Hakimov, and U. Oripova, "Improving energy efficiency in public buildings: Modern technologies and methods," *AIP Conference Proceedings* **3331**, 040060 (2025). https://doi.org/10.1063/5.0306935
26. M. Ibadullayev, S. Begmatov, and A. Tovbaev, "Subharmonic resonance in three-phase ferroresonant circuits with common magnetic cores," *AIP Conference Proceedings* **3152**, 050019 (2024). https://doi.org/10.1063/5.0218907
27. K. Turdibekov *et al.*, "Experimental and statistical methods for studying the modes of electric power systems under conditions of uncertainty," *E3S Web of Conferences* **452**, 04002 (2023). https://doi.org/10.1051/e3sconf/202345204002

28. B. Narzullayev and J. Boboqulov, "Improving reliability based on diagnostics of the technical condition of electric motor stator gutters," *AIP Conference Proceedings* **3331**, 030032 (2025). https://doi.org/10.1063/5.0305735
29. A. Taslimov, F. Raximov, F. Rakhimov, and I. Bakhadirov, "Optimal parameters and selection criteria for neutral grounding resistors in 20 kV electrical networks," *AIP Conference Proceedings* **3331**, 030048 (2025). https://doi.org/10.1063/5.0306108
30. I. Togaev, A. Tovbaev, and G. Nodirov, "Systematic analysis of reactive power compensation in electric networks is essential for improving electricity quality, enhancing system stability, and reducing operational costs," *AIP Conference Proceedings* **3331**, 030099 (2025). https://doi.org/10.1063/5.0305740
31. A. Taslimov, F. Rakhimov, F. Raximov, and V. Mo'minov, "Analysis of the results of sampling the surfaces of sections of rural electric networks," *AIP Conference Proceedings* **3331**, 030041 (2025). https://doi.org/10.1063/5.0305783
32. Urishev, B., and Fakhriddin Nosirov. 2025. "Hydraulic Energy Storage of Wind Power Plants." Proceedings of the International Conference on Applied Innovation in IT.
33. Mukhammadiev, M., K. Dzhuraev, and Fakhriddin Nosirov. 2025. "Prospects for the Development of the Use of Pumped Storage Power Plants in the Energy System of the Republic of Uzbekistan." Proceedings of the International Conference on Applied Innovation in IT.
34. 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
35. 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
36. 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
37. Urishev, B., Fakhriddin Nosirov, Obid Nurmatov, S. Amirov, and D. Urishova. 2021. "Local Energy System Based on Thermal, Photovoltaic, Hydroelectric Stations and Energy Storage System." AIP Conference Proceedings. https://doi.org/10.1063/5.0306446
38. Nurmatov, Obid, Fakhriddin Nosirov, Khusniddin Shamsutdinov, and Dildora Obidjonova. 2025. "Research on Control Systems for Automatic Excitation Regulation Utilizing Fuzzy Logic Methodology." AIP Conference Proceedings. https://doi.org/10.1063/5.0306119
39. Nurmatov O. Large pumping stations as regulators of power systems modes. Rudenko International Conference "Methodological problems in reliability study of large energy systems" (RSES 2020), *E3S Web of Conferences* 216, 01098(2020) https://doi.org/10.1051/e3sconf/202021601098
40. Nurmatov O., Makhmudov T.: Pulatov N. Control of the excitation system of synchronous motors pumping stations //AIP Conference Proceedings, 3152, 040008 (2024) https://doi.org/10.1063/5.0218781
41. Nurmatov O., Nosirov F., Shamsutdinov K., Obidjonova D.Research on control systems for automatic excitation regulation utilizing fuzzy logic methodology. AIP Conference Proceedings *AIP Conf. Proc.* 3331, 040081 (2025) https://doi.org/10.1063/5.0306119
42. Makhmudov T.: Nurmatov O., Ramatov A.N., Site Selection for Solar Photovoltaic Power Plants Using GIS and Remote Sensing Techniques//AIP Conference Proceedings, 3152, 060002 (2024) https://doi.org/10.1063/5.0218779
43. Urishev B., Nosirov F., Nurmatov O., Amirov Sh.,Urishova D. Local energy system based on thermal, photovoltaic, hydroelectric stations and energy storage system *AIP Conf. Proc.* 3331, 070015 (2025) https://doi.org/10.1063/5.0306446
44. Rismukhamedov D., Shamsutdinov K., Magdiev K., Peysenov M., Nurmatov O. Construction of pole-switchable windings for two-speed motors of mechanisms with a stress operating modeAIP Conference Proceedings *AIP Conf. Proc.* 3331, 040059 (2025) https://doi.org/10.1063/5.0305963
45. Rabatuly M., Myrzathan S.A., Toshov J.B., Nasimov J., Khamzaev A. Views on drilling effectiveness and sampling estimation for solid ore minerals. Комплексное Использование Минерального Сырья. №1(336), 2026. https://doi.org/10.31643/2026/6445.01
46. Toshov J.B., Rabatuly M., Khaydarov Sh., Kenetayeva A.A., Khamzayev A., Usmonov M., Zheldikbayeva A.T. Methods for Analysis and Improvement of Dynamic Loads on the Steel Wire Rope Holding the Boom of Steel Wire Rope Excavators. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources 2026; 339(4):87-96 https://doi.org/10.31643/2026/6445.43
47. Zokhidov O.U., Khoshimov O.O., Khalilov Sh.Sh. Experimental analysis of microges installation for existing water flows in industrial plants. III International Conference on Improving Energy Efficiency, Environmental Safety

and Sustainable Development in Agriculture (EESTE2023), E3S Web of Conferences. Том 463. Страницы 02023. 2023. https://doi.org/10.1051/e3sconf/202346302023
48. Zokhidov O.U., Khoshimov O.O., Sunnatov S.Z. Selection of the type and design of special water turbines based on the nominal parameters of Navoi mine metallurgical combine engineering structures. AIP Conf. Proc. 3331, 050022 (2025). https://doi.org/10.1063/5.0306554
49. Khamzaev A.A., Mambetsheripova A., Arislanbek N. **Thyristor-based control for high-power and high-voltage synchronous electric drives in ball mill operations/ E3S Web Conf. Volume 498, 2024/ III International Conference on Actual Problems of the Energy Complex: Mining, Production, Transmission, Processing and Environmental Protection (ICAPE2024) DOI:** https://doi.org/10.1051/e3sconf/202449801011
50. Toshov B.R., Khamzaev A.A. Development of Technical Solutions for the Improvement of the Smooth Starting Method of High Voltage and Powerful Asynchronous Motors/AIP Conference Proceedings 2552, 040018 (2023); https://doi.org/10.1063/5.0116131 Volume 2552, Issue 1; 5 January 2023
51. Toshov B.R., Khamzaev A.A., Sadovnikov M.E., Rakhmatov B., Abdurakhmanov U./ Automation measures for mine fan installations/ SPIE 12986, Third International Scientific and Practical Symposium on Materials Science and Technology (MST-III 2023), 129860R (19 January 2024); doi: 10.1117/12.3017728. Third International Scientific and Practical Symposium on Materials Science and Technology (MST-III 2023), 2023, Dushanbe, Tajikistan.
52. Toshov B.R., Khamzaev A.A., Namozova Sh.R.Development of a circuit for automatic control of an electric ball mill drive. AIP Conference Proceedings 2552, 040017 (2023) Volume 2552, Issue 1; 5 January 2023.
53. Toirov, O., Pirmatov, N., Khalbutaeva, A., Jumaeva, D., Khamzaev, A. Method of calculation of the magnetic induction of the stator winding of a spiritual synchronous motor. E3S Web of ConferencesЭта ссылка отключена., 2023, 401, 04033
54. O. Toirov, A. Khalbutaeva, Z. Toirov. Calculation of the magnetic flux with considering nonlinearities of saturation of the magnetic circuit of synchronous motors, // 3rd International Scientific and Technical Conference on Actual Issues of Power Supply Systems, ICAIPSS 040022, (2023). https://doi.org/10.1063/5.0218821
55. O. Toirov, S. Khalikov. Research and Evaluation of the Reliability Indicators of Pumping Units for Mechanical Irrigation of the Pumping Station "Kyzyl-Tepa", // Power Technology and Engineering, 57 (5), (2024). https://doi.org/10.1007/s10749-024-01720-2
56. O. Toirov, M. Taniev, B. Safarov, Z. Toirov. Simulation model of an asynchronous generator integrated with a power supply system at different wind speeds, // AIP Conference Proceedings, 3331 (1), 060025, (2025). https://doi.org/10.1063/5.0305672
57. O. Toirov, Sh. Azimov, Z. Toirov. Improving the cooling system of reactive power compensation devices used in railway power supply // AIP Conference Proceedings, 3331, 1, 050030, (2025). https://doi.org/10.1063/5.0305670
58. O. Toirov, W. Yu. Non-Intrusive Load Monitoring Based on Image Load Signatures and Continual Learning // Proceedings of 2025 2nd International Conference on Digital Society and Artificial Intelligence, (2025) https://doi.org/10.10.1145/3748825.3748963
59. O. Toirov, Sh. Azimov, Z. Najmitdinov, M. Sharipov, Z. Toirov. Improvement of the cooling system of reactive power compensating devices used in railway power supply // E3S Web of Conferences, 497, 01015, (2024). https://doi.org/10.1051/e3sconf/202449701015
60. 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) RSES 2022. https://doi.org/10.1051/e3sconf/202338401033
61. 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, 040031 (2024). https://doi.org/10.1063/5.0218873