Analytical assessment of the efficiency of moisture detection methods in high-voltage SF_6 circuit breakers

Khasan Murodov[1], Timurbek Khakberdiyev[1, a)], Saidamirkhon Oripov[2], Xumoyun Xaydarov[3]

[1] Navoi State University of Mining and Technologies, Navoiy, Uzbekistan
[2] Tashkent State Technical University, Tashkent, Uzbekistan
[3] Andijan State Technical Institute, Andijan, Uzbekistan

[a)] Corresponding author: timurbekhaqberdiyev@gmail.com

Abstract. This article examines various techniques used to detect moisture in the SF_6 gas of high-voltage circuit breakers and evaluates their operational effectiveness. The pros and cons of each detection technology are compared, with particular emphasis on their capability for real-time monitoring. According to the analysis findings, a hybrid system, which combines two already available forms of measurements, is presented to improve the accuracy and reliability. The results indicate that the enhanced moisture sensing method can extend the service life of high-voltage circuit breakers, increase maintenance efficiency, as well as reduce the frequency of failures within power systems.

INTRODUCTION

Modern power systems are characterized by the large use of high-voltage SF_6 circuit breakers with high dielectric strength and good arc-quenching performance. The quality of such equipment, however, depends significantly on the quality of SF_6 gas especially on its moisture level. A rise in moisture causes a substantial decrease in dielectric strength of the gas, hastens the ionization, and causes the instability of an electric arc inside the breaker, which can be a cause of partial discharges. Consequently, the risk of the circuit breaker failure rises and unexpected failures may occur in power networks [1-2]. There are different causes of moisture entering the SF_6 gas compartment which include installation errors, leakages in the systemduring the maintenance process, degradation of internal insulation materials and corrosion processes. Thus, moisture in SF_6 gas needs to be detected and continuous monitoring is the key to the high-voltage equipments safety and reliability in the long run. Within recent years, a range of technologies have been created to detect moisture in SF_6 gas, but the analytical research that comprehensively evaluates their benefits and drawbacks still is not made [3-5].

Though, many research papers are devoted to the study of single technologies, capacitive sensors, optical methods, dew-point measurement techniques, and electrochemical sensors, the comparative analysis of their accuracy, sensitivity, stability, and appropriateness to online monitoring has not been fully provided. The most important aim of the proposed research is to examine the most popular moisture detection techniques of SF_6 gas, evaluate operational efficiency and give scientifically-based comparison. Besides, the article suggests a hybrid approach, which incorporates two of the most effective existing technologies now, the purpose of which is to improve the overall performance of measurements and reach high detection efficiency [6].

The impact of moisture in SF_6 gas.

The outstanding dielectric strength of sulfur hexafluoride (SF_6) gas is one of the greatest strengths of this substance. Nevertheless, this property can be greatly impaired by the presence of moisture in the gas. The ionization of water vapor in SF_6 by an electric field lowers the insulation capacity of the equipment significantly. The negative influence of moisture in SF_6 occurs in a variety of forms. As an example, the electric field can cause the moisture to condense or freeze. When the temperature is low, water vapor may change into microdroplets or ice crystals forming an asymmetric electric field between the electrodes and this leads to further enhancement of the possibilities of partial discharges. With time, there will be partial discharge which can cause the breakdown of insulation, erosion and corrosion of the contact elements. These processes get accelerated, which heightens the chances of failure of high-voltage equipment. Besides having direct effect in reducing the dielectric properties of the gas, the existence of moisture also has adverse effects on heat transfer processes. Consequently, the interior temperature of the device can increase, thus overheating contact or leading to rapid wear. As a result, one of the most important predictors of the reliability of the insulation is constant monitoring of moisture content in SF_6 gas. To have SF_6 circuit breakers operating optimally, the moisture content should usually be associated with a dew point that is below -40 ^{0}C. Such stringent conditions are due to the fact that moisture at small percentage rates of parts per million (ppm) of SF_6 is a deadly risk when applied to high voltage conditions. The considerations above emphasize the need to measure the moisture and monitor it in SF_6-insulated circuit breakers. The inability to find moisture in time may decrease the safety of the whole power network, raise the number of unplanned disruptions, and raise the cost of maintenance. Thus, the adoption of real-time monitoring systems based on the latest diagnostic technologies is regarded as one of the crucial demands associated with providing the power systems with the safety [7-12].

DATA ANALYSIS

Moisture Detection Technologies. Dew-Point Measurement. It is the temperature at which the condensation of water vapor in a gas starts. In contemporary hygrometers, the determining factor of the presence or absence of moisture within SF_6 gas is the dew-point temperature. The greatest advantages of this method includes the fact that it can measure extremely low moisture levels to a high degree of measurement. Nevertheless, dew-point measurements can be related to the temperature and pressure of the gas, and extra data processing and correction are necessary in actual working conditions [13-15].

$$e_s(T_d) = 6.112 \cdot e^{\left(\frac{17.62 T_d}{243.12+T_d}\right)} \quad (1)$$

here: $e_s(T_d)$ – the partial pressure of water vapor (in millibars) at the dew point

T_d- measurement of the dew-point temperature (^{0}C)

6.112 – 273K the initial value of the pressure

17.62 – the empirical coefficient of water vapor as a function of temperature

243.12 – the parameter used to fit the saturated water vapor curve

SF_6 – moisture concentration in the gas, hbm:

$$\text{ppmv}=\frac{e_s(T_d)}{P_{SF6}} 10^6 \quad (2)$$

ppmv – one part per million by volume

P_{SF6} – the total pressure of the gas (hPa)

If the mass fraction is required:

$$\text{ppmm}=\text{ppmv}\times\frac{M_{H_2O}}{M_{SF6}} \quad (3)$$

ppmm - one part per million by mass

M_{H_2O} – molar mass of water

M_{SF6} – molar mass of SF_6 gas [16].

Dielectric capacitance technique. Dielectric characteristics of the SF_6 gas are also moisture sensitive, and the presence of water molecules in the gas will result in alterations of the dielectric capacitance. The amount of moisture is measured by the assistance of dielectric capacitance sensors. The benefit of this type of work is that it can be paired with online surveillance, and one can work on it in real time. The drawback is that the measurement may be influenced by a temperature and pressure state. The capacitance between two electrodes is calculated in the following way [17,18].

$$C = \varepsilon_0 \varepsilon_r \frac{S}{l} \quad (4)$$

here: C-capacitance (Farad), $\varepsilon_0 - 8{,}85 \cdot 10^{-12}$F/m - dielectric permittivity constant of vacuum, ε_r - relative dielectric permittivity of SF_6 gas, S - electrode surface area (m2), l - distance between dielectrics (m) [19-21].

When water vapor enters SF_6, its relative dielectric constant (ε_r) has the following dependence:

$$\varepsilon_r = \varepsilon_{dry} + kC_{H_2O} \quad (5)$$

here: ε_{dry} – dielectric constant of dry SF_6 gas, k - experimental constant empirical coefficient

C_{H_2O} – concentration of water vapor in the gas (millibars).

Optical method. The optical sensors are based on the principles of infrared radiation or a laser and measure the water molecules in a gas with the help of spectral analysis. The technique offers quick and very accurate measurements, and it is also non-contact, i.e. the gas flow does not stop. Nonetheless, optical techniques are complicated instruments that are expensive.

$$I = I_0 e^{-a^{C_{H_2O}L}} \tag{6}$$

here: I_0 – initial light intensity, I - light intensity reaching the detector, A - absorption coefficient (m^2/mol), C_{H_2O} - concentration of water vapor in the gas (millibar), L - optical path length (m).

The greater the amount of light consumed, the more the amount of moisture the gas contains. The greater the amount of light consumed, the more the amount of moisture the gas contains.

Operating principle:

1. A laser or an infrared LED source emits light at a specific wavelength (usually 1.37 μm or 2.7 μm).
2. The gas SF_6 is where light is passed through.
3. To some degree, this light is absorbed by the water vapor.
4. The detector is an indicator of the intensity of light reduction.
5. The microprocessor is used to compute C_{H_2O}according to the law of Lambert-Beer.

Sensory (electronic) methods. The moisture level in the gas is measured by sensor measuring devices based on electrochemical or electric sensors. The benefit of this approach is that the sensors are miniature, cheap and can be incorporated into the system without much difficulty. Nevertheless, to work in the long-term, sensors have to be calibrated and undergo frequent maintenance to ensure high accuracy.

TABLE 1. Technical specifications of humidity measurement technologies in SF_6 gas

Moisture-Measurement Methods	Operating temperature range (^{0}C)	Humidity measurement range (ppm)	Accuracy level (%)	Response time	Sensitivity (temperature-dependent)	Suitability for online monitoring
Dew-Point Measurement	-80…+20	1 – 3000	±1 %	5–15 s	Moderate	Yes
Dielectric-capacitance	-40…+85	10 – 2000	±3 %	1–3 s	High	Yes
Optical method	-20…+60	50 – 3000	±2 %	3–10 s	Moderate	Yes (limited)
Sensory (electronic)	-20…+80	100 – 2000	±2.5 %	2–5 s	Low	Limited

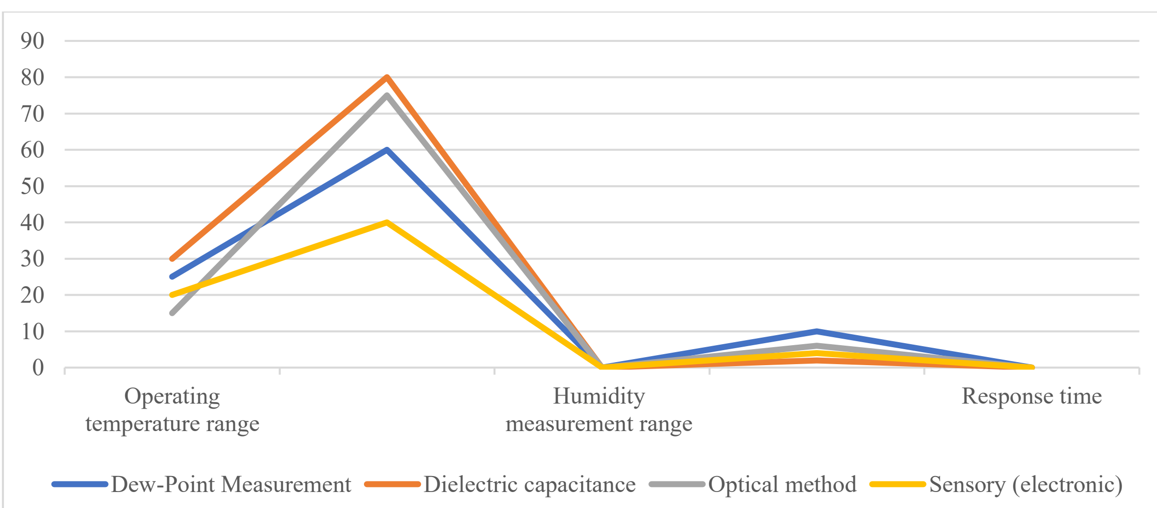

FIGURE 1. Analysis of operating temperature, humidity measurement interval, and response time for humidity measurement technologies

PROPOSED HYBRID SYSTEM

In the foregoing section, different ways of measuring the moisture content in high-voltage exhaust gases were discussed. Considering the pros and cons of these already existing methods, we suggest a hybrid solution of optical-capacitive sensors. Such an integrated approach is a combination of high level of sensitivity and accuracy of capacitive sensors on the one hand and the possibility of fast response and long-term monitoring of optical elements on the other hand. Consequently, the humidity will be able to be monitored in the switch in real time and precisely [27-56]. The conceptual nature of the hybrid functioning is to guarantee that measurements are compatible on the basis of two independent physical laws. In case the dielectric measuring device is erroneous because it is sensitive to temperature variations then the optical module identifies the error and rescues the result with the error elimination factor. A real-time automatic adaptation algorithm is implemented in the hybrid system, and the measurements of elements are analyzed by optimizing the measurement parameters. Consequently, the device retains the stability and the accuracy of the measurement results over a long period. The digital form of the signal of the modules of the measuring element is constantly processed using a microcontroller in this complicated system of measurements. This enables you to check the status of the SF_6 circuit breaker insulation online.(Figure 2)

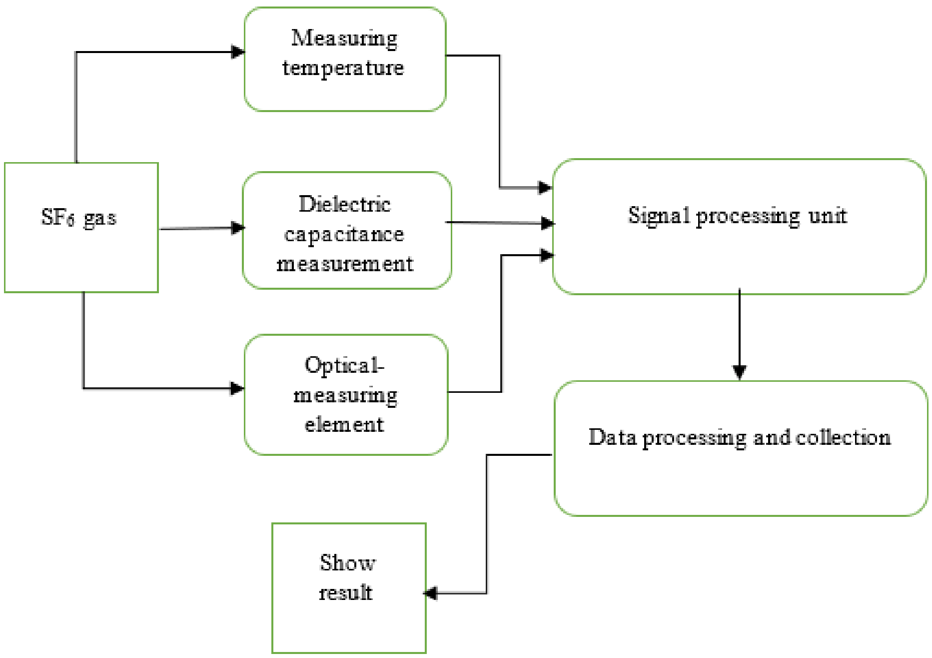

FIGURE 2. Functional diagram of the dielectric-optic hybrid humidity monitoring system.

1. The SF_6 gas is the SF_6 (hydrofluoric sulfur) gas, meaning the object of measurement of the system. Such gas is very popular in high-voltage circuit breakers as a dielectric medium. Its water content has a direct influence on the electrical strength and reliability of operation of the gas. So, accurate moisture regulation in the SF_6 medium is a significant technical strictness.

2. One of the factors which are the most significant in a hybrid system is temperature which impacts both measurement channels. As this temperature change in the gas with the temperature measuring unit modifies the dielectric constant and the optical attenuation coefficient, the system has a temperature measurement function. The denser the gas the higher the temperature and vice versa, and this lowers the dielectric constant. Thus, the entire relationship:

$$\varepsilon_r = f(T) \tag{7}$$

$$\varepsilon_r = \varepsilon_{r0}(1 + \alpha(T - T_0)) \tag{8}$$

here: ε_r - dielectric permittivity, T - temperature, α α - temperature coefficient. (7) and (8) the formula for the temperature dependence of the capacitance has the form:

$$C(T) = \varepsilon_0 \varepsilon_{r0}(1 + \alpha(T - T_0))\frac{S}{d} \tag{9}$$

Consequently, the change in value of dielectric permittivity as a function of temperature change has a direct impact on the capacitance value. Hence the variations in temperature within the SF_6 circuit breaker can be established by variations in capacitance between the differential capacitance. The dielectric measuring element is a storing of energy.

$$W = \frac{1}{2} C(T) U^2 \tag{10}$$

As the temperature rises, ε_r reduces and as the C(T) bond reduces and the energy of charge retention decreases. Thus, the dielectric component of the hybrid system is a temperature sensitive, but fast channel. The optical channel on the other hand, is a slow and highly temperature compensated channel [22-25]. Another important element of this relationship is in a hybrid measurement system as the dielectric capacitance measuring element is sensitive to a change in temperature and along with the optical measuring element, enhances accuracy of measurement results. Temperature resistance of the system is dependent on the physical characteristics of SF_6 gas and stability of the material of measurement element. Practical experiments SF_6 gas normally has an operating temperature of between -40 to +80 ^{0}C. At temperatures lower than -40 ^{0}C, the gas density becomes large and the change in dielectric is nonlinear; At higher temperatures, above +80 ^{0}C, the gas pressure is increasing, and the linearity of optical absorption is broken. Hence, the heat-resistant dielectric materials shield the module of the measuring element.

3. A dielectric capacitive measurement unit. A dielectric measure producing element that identifies the moisture content of gas SF_6 based on the change in capacitance. As the water vapor concentration of the gas rises, its dielectric constant varies hence it varies the value of capacitance between the electrodes. It is a change in form of electrical signal and it is utilized as one of the primary indicators of humidity.

4. Unit of optical measuring. Optical measuring element, which measures humidity, depending on the light attenuation, absorption, or refraction coefficients. The optical radiation is altered by the water vapor in SF_6 gas and is measured by the measuring element. The benefit of the optical method is that, it is not directly acting on the gas environment but rather it is not prone to the influence of external electromagnetic interference.

5. Signal processing unit. Signals of dielectric, optical and temperature measuring elements are processed through a digital device in this unit where these signals are digitized, filtered and compensated. The measurement results are then merged depending on a hybrid algorithm to achieve one moisture value. At this point the system comparing the two methods measurements is chosen and the best one is selected.

6. Data Processing and Collection Unit. This unit stores, analyses, and transmits data of measurement that is processed. The system interacts with external devices in case of need. This, in its turn, makes it possible to monitor remotely.

7. Result display block. This block works as a user interface, where the display of the measurement results is seen in a digital form. The display or digital port indicates the humidity, temperature and the system status in general. This block enhances the convenience of operation of the system [26].

The dielectric measurement unit in the proposed hybrid system is founded on the variation in the capacitance of SF_6 gas and calculates the functional dependence of its dielectric constant (ε_r) and the percentage of moisture. Meanwhile, the optical measuring module is another independent parameter which records the alterations in the extent of light absorption and refractive index. By working parallel with both modules, the measurement results are verified with each other and the final value is obtained with high accuracy.

The advantages of the hybrid method are:

1. High accuracy: Capacitive sensors are sensitive to any slight change in moisture, and can be used to determine accuracy even during long term measurements.
2. Quick answer: It is possible to detect sudden changes of moisture in real-time using optical components.
3. Stable operating mode: The hybrid system provides stability during operation at different temperature, pressure and electric field conditions, which is needed in high-voltage SF_6 circuit breakers.
4. Long-term monitoring: With the help of the hybrid approach, long-term monitoring of moisture in the circuit breaker can be performed, which is capable of predicting maintenance and malfunctions.
5. Practical convenience of use: It is possible to transfer the measurement outcomes to a digital system, which leads to the effective implementation of automated diagnostic and preventive measures.
6. Maximum efficiency: Capacitive and optical sensors create the best combination in terms of high sensitivity and quick reaction as opposed to conventional techniques and hence reliability is enhanced in GIS systems.

CONCLUSION

To sum up, it may be stated that the evaluation of the techniques of the moisture content high-voltage electrolytic gas circuit breakers measurement was taken into account. The dew point technique is used in this instance to calculate the content of the moisture in the SF_6 gas on the basis of few physical parameters - temperature and pressure and the obtained results are associated with high precision. But, as the primary drawback of such a technique is that it is very sensitive to temperature variations, there should be algorithms to its use in continuous monitoring systems. The change in capacitance under the dielectric capacitance method is gauged by sensors according to the change in the humidity that offers continuous and immediate check-ups. The benefit of this approach is that it is small and consumes less energy. In measuring the degree of moisture using the optical method, it has high accuracy using the degree of light absorption or refractive index. Nevertheless, optical components are very fine and expensive, but therefore this method is mostly employed in a laboratory setup. Sensor (electronic) modules are sensor modules which measure humidity, temperature and pressure simultaneously and send it as a digital signal. It is a low cost, small size method that needs thermal insulation; in order to guarantee long operating life in high voltage gas operating conditions. As per the analysis findings, the dielectric capacitance and optical process is the most effective. Under this type of hybrid system, dielectric capacitance method offers a simple accuracy in determining the level of humidity, as the capacitance value concretly increases with increment in humidity. In the optical sensor method, it is possible to monitor in real time. Therefore, the system constructed on the principles of these two approaches is a good solution that will allow constant control of humidity in high-voltage electrolytic gas extinguishers and enhance reliability and minimize the chances of accidents.

REFERENCES

1. Murodov X.Sh., Haqberdiyev T.Z. Assessment of the effect of moisture on the reliability of high-voltage SF_6 circuit breakers and analysis of monitoring system methods // International journal of advanced technology and natural sciences, Vol.3(6) 2025. – N. 86. – P.
2. O.O. Zaripov, S.J. Nimatov, Y.M. Yeralieva, S.O. Zaripova, M.A. Zakirov, D.M. Nomozova, J.T. Akhmedov, Akram Tovbaev. Calculation of the nominal power and electrical energy of the hydro power plant on an electronic calculator. E3S Web Conf. Volume **486**, 2024. IX International Conference on Advanced Agritechnologies, Environmental Engineering and Sustainable Development (AGRITECH-IX 2023). https://doi.org/10.1051/e3sconf/202448601027
3. Mukhtorkhon Ibadullayev; Shavkat Begmatov; Akram Tovbaev. Subharmonic resonance in three-phase ferroresonant circuits with common magnetic cores. AIP Conf. Proc. **3152,** 050019 (2024) https://doi.org/10.1063/5.0218907
4. Akram Tovbaev, Muxtarxan Ibadullayev and Mohinur Davronova. Study of subharmonic oscillation processes in ferroresonance circuits. E3S Web of Conf. Volume **525**, 2024. IV International Conference on Geotechnology, Mining and Rational Use of Natural Resources (GEOTECH-2024). https://doi.org/10.1051/e3sconf/202452503008
5. Akram Tovbaev., Islom Togaev., Uktam Usarov., Gulom Nodirov, Reactive power compensation helps maintain a stable voltage profile across the network, AIP Conf. Proc. **3331,** 060014 (2025). https://doi.org/10.1063/5.0307209
6. Shukhrat Abdullaev., Ziyodullo Eshmurodov., Islom Togaev, A systematic analysis of the gradual increase in quality indicators of electricity using reactive power sources involves several steps, AIP Conf. Proc. **3331**, 040051 (2025). https://doi.org/10.1063/5.0306786
7. Bobur Narzullayev; Javokhir Boboqulov, Improving reliability based on diagnostics of the technical condition of electric motor stator gutters, AIP Conf. Proc. **3331**, 030032 (2025). https://doi.org/10.1063/5.0305735
8. Islom Togaev., Akram Tovbaev., Gulom Nodirov, Systematic analysis of reactive power compensation in electric networks is essential for improving electricity quality enhancing system stability, and reducing operational costs, AIP Conf. Proc. **3331**, 030099 (2025) https://doi.org/10.1063/5.0305740
9. Abdurakhim Taslimov., Farrukh Rakhimov., Feruz Rakhimov., Vaxobiddin Mo'minov, Analysis of the results of sampling the surfaces of sections of rural electric networks, AIP Conf. Proc. **3331,** 030041 (2025) https://doi.org/10.1063/5.0305783
10. Raximov, F., Taslimov, A., Majidov, A., & Norqulov, A. (2024). Optimization of losses by switching to higher voltage in distribution networks. In E3S Web of Conferences **(Vol. 525, p. 03009).** EDP Sciences. https://doi.org/10.1051/e3sconf/202452503009

11. A.Tovboyev, I.Togayev, I.Uzoqov, 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
12. G.Boynazarov, A. Tovbaev, U. Usarov, Methology of experimental research of voltage quality in electrical circuit, E3S Web of Conferences 548, 03009 (2024) https://doi.org/10.1051/e3sconf/202454803009
13. N.Ataullayev, A.Norqulov, B.Muxammadov, A.Majidov, 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
14. Amirov S.F., Ataullayev A.O., Sayidov M.K., Togayev I.B. Methods of reduction of interference signals in electromagnetic conductors that measure fluid flow Journal of Physics: Conference Series, 2094(5), 052053 (2021) 10.1088/1742-6596/2094/5/052053
15. Olimov J., Ramazonov B., Sayfiyev S. Increasing efficiency of induction motor by predictive control system //E3S Web of Conferences. – EDP Sciences, 2024. – T. 525. – C. 03006. https://doi.org/10.1051/e3sconf/202452503006
16. Murodov K., Karshibayev A. Development of the management system of technical indications of high-power charger-discharger rectifier device //E3S Web of Conferences. – EDP Sciences, 2023. – T. 417. – C. 03012. https://doi.org/10.1051/e3sconf/202341703012
17. Tatkeyeva G. et al. Experimental research of the developed method to determine the network insulation for ungrounded AC systems in laboratory conditions //2022 International Conference on Electrical, Computer and Energy Technologies (ICECET). – IEEE, 2022. – C. 1-4. 10.1109/ICECET55527.2022.9873012
18. Ataullaev N. O., Dziaruhina A. A., Murodov K. S. Static Characteristics of Magnetic Modulation DC Converters with Analog Filter // Science and technology. – 2023. – T. 22. – №. 5. – C. 428-432. https://doi.org/10.21122/2227-1031-2023-22-5-428-432
19. Murodov K., Karshibayev A., Abdullayev S. Analysis of the process of balanced charging of the battery group with high capacity //E3S Web of Conferences. – EDP Sciences, 2024. – T. 548. – C. 03012. https://doi.org/10.1051/e3sconf/202454803012
20. Ikromjon Rakhmonov; Zamira Shayumova; Kamal Reymov; Laziz Nematov Energy efficiency indicators // AIP Conf. Proc. 3152, 020002 (2024) https://doi.org/10.1063/5.0218763
21. Ikromjon Rakhmonov; Dinora Jalilova; Zamira Shayumova; Nargiza Karimova; Gulmira Abidova; Khurshida Khalikova Voltage regulation issues in spinning enterprises // AIP Conf. Proc. 3331, 080009 (2025) https://doi.org/10.1063/5.0306210
22. Dinora Jalilova; Gulnora Kasimova; Zamira Shayumova; Gulmira Abidova Current status of ensuring power quality in spinning mills // AIP Conf. Proc. 3331, 070021 (2025) https://doi.org/10.1063/5.0306211
23. Ikromjon Rakhmonov; Sarvarjon Usmanaliev; Zamira Shayumova; Mirjalol Ruzinazarov Carbon dioxide (CO2) filtering, capture, and storage technologies // AIP Conf. Proc. 3331, 040024 (2025) https://doi.org/10.1063/5.0305715
24. Khudayarov M., Makhmudov T., Fayziyev S. Tuning hyperparameters of artificial neural networks to solve problems of calculating steady-state modes and electricity losses in distribution networks //AIP Conference Proceedings. – AIP Publishing LLC, 2025. – T. 3331. – №. 1. – C. 030066. https://doi.org/10.1063/5.0305698
25. Khudayarov M., Sherzod F. Methodology for evaluating the efficiency of electrical networks of power supply systems //AIP Conference Proceedings. – AIP Publishing LLC, 2024. – T. 3152. – №. 1. – C. 030002. https://doi.org/10.1063/5.0218810
26. Shaymamov B. et al. Probe of process of multiple-loop chains of parallel and consecutive joints //E3S Web of Conferences. – EDP Sciences, 2020. – T. 216. – C. 01142. https://doi.org/10.1051/e3sconf/202021601142
27. 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.
28. 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.
29. Bobojanov M.K., Karimov R.Ch., Popkova O.S., Tuychiev F.N., Makhmutkhanov S.K. Analysis of the results of experimental studies of the arc furnace DSP-30. // *Power Engineering Research & Technology*. 27(2), 2025. pp. 126–137. https://doi.org/10.30724/1998-9903-2025-27-2-126-137
30. 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.
31. R. K. Kurbaniyazov, A. M. Reimov, A.T. Dadakhodzhaev, Sh. S. Namazov, B. M. Beglov. Nitrogen-phosphoric fertilizers produced by introduction of Central Kyzylkum phosphate raw material into ammonium nitrate melt. Russian

Journal of Applied Chemistry. Russ J Appl Chem (2007) 80(11): 1984-88. https://doi.org/10.1134/S1070427207110456
32. Namazov, Sh.S., Kurbaniyazov, R.K., Reimov, A.M., Beglov, B.M. Hardness of the granules of ammonium nitrate doped with the Central Kyzylkum Phosphorite. Russian Journal of Applied Chemistry. Russ J Appl Chem (2007) 81(6): 1103–1106. http://dx.doi.org/10.1134/s1070427208060402.
33. Kurbaniiazov, R.K., Reimov, A.M., Namazov, Sh.S., Beglov, B.M. Nitrogen-phosphoric fertilizers obtained by interaction of the concentrated solutions of ammonium nitrate with the mineralized mass of the phosphorites of Central Kyzylkum. Russian Journal of Applied Chemistry. Russ J Appl Chem (2009) 82: 1123. https://link.springer.com/journal/11167
34. 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
35. 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/
36. Reymov Akhmed, Namazov Shafoat. Nitrogen-phosphorous fertilizers on the base of concentrated ammonium nitrate solution and Central Kyzylkum phosphate raw material. Polish Journal of Chemical Technology 16(3), Sep 2014, 30-35. https://doi.org/10.2478/pjct-2014-0046
37. Alisher Eshimbetov, Shahobiddin Adizov, Inderpreet Kaur, Akhmed Reymov. Is it possible to differentiate between 2-phenylaminodihydro-1,3-thiazine from 2-phenyliminotetrahydro-1,3-thiazine by spectral methods? New glance to the old problem. European Journal of Chemistry 12 (1) (2021). https://doi.org/10.5155/eurjchem.12.1.77-80.2068
38. A.Ahmadjonov, U.Alimov, P.Tuychi, A.Seitnazarov, A.Reimov, Sh.Namazov, S.Sadullayev. Effect of temperature on the kinetics of the process of nitric acid decomposition of Arvaten serpentinite. IOP Conf. Series: Earth and Environmental Science 1142 (2023) 012034. https://www.scopus.com/pages/publications/85151285667
39. Xudoyberdiev J., Reymov A., Kurbaniyazov R., Namazov S., Badalova O., Seytnazarov A. Mineral Composition of Nodular Phosphorite of Karakalpakstan and its Processing into Simple Superphosphate. (2023) E3S Web of Conferences, 449, art. no. 06005. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85178595919&doi=10.1051%2fe3sconf%2f202344906005&partnerID=40
40. Kosnazarov K., Ametov Y., Khabibullaev A., Reymov A., Turdimambetov I., Shaniyazov S., Berdimuratova A. Characteristics of dust-salt transfer from the dried bottom of the Aral Sea and the Aral region, as well as their lossout. E3S Web of Conferences. https://www.scopus.com/pages/publications/85212840616
41. Seyilkhanova A., Reymov Q., Eshmuratov A., Gulimbetov B., Medetov M., Reymov A., Berdimuratova A., Shaniyazov Sh. E3S Web of Conferences ISSN: 25550403Volume: 575. https://www.scopus.com/pages/publications/85212825022
42. Turdimambetov I., Murgaš F., Victor F., Oteuliev M., Madreimov A., Shamuratova G., Atabayev S., Reymov A. Geojournal of Tourism and Geosites. ISSN: 20650817, Volume: 57 Pages: 1941 – 1951. https://www.scopus.com/pages/publications/85213872579
43. Temirov G., Alimov U., Seytnazarov A., Reymov A., Namazov S., Beglov B. Rheological Properties and Composition of Products of Phosphogypsum Conversion with Sodium Carbonate. Russian Journal of General Chemistry. ISSN: 10703632 Volume: 94 Issue: 7 Pages: 1837 – 1847. https://www.scopus.com/pages/publications/85202786813
44. Reymov A., Turdimambetov I., Pirnazarov N., Shaniyazov Sh., Absametova D., Baymurzaev A., Orazbaev A., Usnatdinov A.,Tajetdinov S. Exploring novel techniques for measuring and identifying minuscule dust particles in the atmosphere. E3S Web of Conferences ISSN: 25550403 Volume: 575. https://www.scopus.com/pages/publications/85212822728
45. Chavliyeva F., Turakulov B., Kucharov B., Erkayev A., Reymov A., Karshiboev M., Mamajonov M. Study of obtaining potassium hydroxide by electrochemical method on the bases of flotation and hallurgic potassium chloride. New Materials, Compounds and Applications ISSN: 25217194 Volume: 8 Issue: 2 Pages: 244 – 253. https://www.scopus.com/pages/publications/85204364412
46. Kuldasheva S., Aziza A., Kulmatov R., Karimova G., Dauletbayeva R., Nortojiyeva G., Reymov A. Study and assessment of mineralogical, chemical and granulometric composition of volatile soil-sand aerosols from the dried-out part of the Aral Sea. E3S Web of Conferences ISSN: 25550403 Volume: 575. https://www.scopus.com/pages/publications/85212848932
47. M. Medetov, D. Musaev, U. Shakarbaev, A. Yusupova, J. Tajibaeva, A. Reymov, A. Yusupova, D. Bazarbaeva, B. Gulimbetov. Insect fauna of the Republic of Uzbekistan: Rare true bugs (Hemiptera, Heteroptera). Regulatory

Mechanisms in Biosystems ISSN: 25198521 Volume: 15 Issue: 4 Pages: 882 – 888. https://www.scopus.com/pages/publications/85218798691
48. Kurbaniyazov R.K., Khudoyberdiev J.H., Reymov A.M., Namazov Sh.S., Radjapov R., Seytnazarov A.R. Characteristics of nodular phosphorites of karakalpakstan and their processing into granular simple superphosphate. ChemChemTech ISSN: 05792991 Volume: 68 Issue: 1 Pages: 109 – 119. https://www.scopus.com/pages/publications/85211354040?origin=resultslist
49. M.ZH.Medetov, J.K.Abdullaeva, A.M. Reymov, A.M.Miratdinova, A.K.Seytmuratov, J.D.Tajibaeva, R.S.Kadirov, N.A.Utemuratov, S.K.Kimyonazarov, J. Kudratov, R.S.Urazova, X.X.Keldiyova, U.B.Uralov. Diversity of true bugs (Hemiptera: Heteroptera) of the Southern Aral Sea Region, Uzbekistan. Biodiversitas ISSN: 1412033X Volume: 26 Issue: 7 Pages: 3125 – 3135. https://www.scopus.com/pages/publications/105014219940?origin=resultslist
50. Ulugbek Urinov, Nilufar Hamidova and Ilhom Mirzakulov . Chemical technology of oligomers production from homopolymer based on epichlorohydrin and morpholine. E3S Web of Conferences 497, 03030 (2024) ICECAE 2024. https://doi.org/10.1051/e3sconf/202449703030
51. Bakhtiyor, K., Gafurov, B., Mamatkulov, A., Shayimov, F., Tukhtaev, B. AIP Conference Proceedings, 3331(1), 080001. https://doi.org/10.1063/5.0306044
52. Khusanov, B., Keunimjaeva, A., Jalelova, M., Rustamov, S. AIP Conference ProceedingsOpen source preview, 2024, 3152(1), 030024. https://doi.org/10.1063/5.0218924
53. Khusanov, B., Arzuova, S., Radjapov, Z., Babaev, O. AIP Conference ProceedingsOpen source preview, 2024, 3152(1), 030028. https://doi.org/10.1063/5.0219241
54. Urishev, B., F. Artikbekova, D. Kuvvatov, F. Nosirov, and U. Kuvatov. 2022. “Trajectory of Sediment Deposition at the Bottom of Water Intake Structures of Pumping Stations.” IOP Conference Series: Materials Science and Engineering, 1030(1). https://doi.org/10.1088/1757-899X/1030/1/012137
55. Nosirov, Fakhriddin, Abdurasul Juraev, Ibragim Khamdamov, and Nurmukhammed Kuvatov. 2023. “Economic Calculation of a Photoelectric Station for Degradation Processes.” AIP Conference Proceedings. https://doi.org/10.1063/5.0130642
56. Nosirov, Fakhriddin, Oleg Glovatsky, Bekzod Khamdamov, and Armen Gazaryan. 2023. “Increasing the Stability of the Supply Hydraulic Structures.” AIP Conference Proceedings. https://doi.org/10.1063/5.0218867