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Assessment of the role of reactive power sources in improving power quality in electric power supply systems

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Assessment of the role of reactive power sources in improving power quality in electric power supply systems

Akram Tovbaev[1], Islom Togaev[1,a], Gulom Nodirov[2], Mohinur Shoyimova[1], Kamal Reymov[3]

[1] *Navoi State University of Mining and Technologies, Navoiy, Uzbekistan*
[2] *Samarkand State of architecture and Construction University, Samarkand, Uzbekistan*
[3] *Karakalpak State University named after Berdakh, Nukus, Uzbekistan*

[a)] *Corresponding author: togayev.islom@mail.ru*

Abstract. In this article, it is noted that electrical machines, transformers, and distribution networks are experiencing increasing losses. The presence of higher-order harmonic components leads to additional heating of transformer windings and a significant rise in power losses. As a consequence, the insulation undergoes accelerated ageing, resulting in a shortened service life of electrical equipment and a growing number of failures in cable networks. The installation of compensation devices may create a risk of parallel resonance between the network inductance and compensation capacitors or filter-compensation units. Resonant operating conditions cause a substantial increase in currents flowing through the capacitors, which can lead to malfunction or complete failure of downstream equipment. The situation also contributes to increased capital expenditures and operational costs, because equipment must be replaced prematurely, and additional organizational and technical measures are required to improve the quality of electrical energy. High-frequency electromagnetic microprocessor noise produces a specific negative influence on relay protection and automation systems. Excessive harmonic distortion can disrupt their correct operation and may lead to false tripping or malfunction of relay protection and automation elements.

INTRODUCTION

One of the most critical parameters determining the quality of electrical energy in distribution networks is the distortion of the sinusoidal waveform of currents and voltages. Alternating-current circuits-including currents, voltages, and the switching laws of controlled elements-represent periodic functions of time. These quantities can be mathematically expressed and analyzed through flourier series [1].

$$f(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty} A_n \sin\left(nw_1 t + \psi_n\right) \tag{1}$$

A_n- the complex amplitude of the n-this harmonic component.

$$A_n(t) = \frac{1}{T}\int_0^T f(t)e^{-jnw_1 t}\,dt \tag{2}$$

In power supply systems, one of the most important parameters that determine the quality of electrical energy is the distortion of the sinusoidal waveform of currents and voltages. Alternating-current circuits (currents, voltages, and the governing laws of switching elements) are periodic functions of time and can be expressed by a flourier series [2-5]. In 10–0.4 kV distribution networks, harmonic distortions are generally insignificant and do not cause any serious impact on the operation of the system. However, they may interfere with the functioning of low-power electrical devices. Under symmetrical loading conditions, the phase currents at the fundamental frequency form a positive-sequence system. For this reason, the fundamental-frequency current in the neutral conductor becomes equal to zero. Typically, the low-voltage winding-being directly connected to the load-is configured in a star connection, whereas the high-voltage winding is connected in a delta configuration. This winding arrangement is widely used in distribution networks. If both transformer windings are connected in a star configuration with the neutral grounded, the triple harmonic components gain a path to propagate toward the high-voltage side. Consequently, these harmonics may be present in both windings of the transformer.

TABLE 1. Harmonic components of phase A current and voltage

n	Current			Voltage		
	Minimum	Average	Maximum	Minimum	Average	Maximum
3	5.51	10.61	15.79	0.10	0.26	0.83
5	2.65	6.21	10.53	0.71	1.59	2.43
7	0.20	3.68	8.20	0.14	0.82	1.42
9	0.13	1.16	3.92	0	0.24	0.70
11	2.89	6.68	12.96	0.38	0.98	1.74
13	0.12	2.02	7.87	0	0.37	1.03
15	0	0.50	2.70	0	0.14	0.40

In some cases, the distortion factor of the current waveform at cable inlets exceeds 30%. In indoor distribution networks, the distortion levels of both current and voltage are considerably higher. The total harmonic distortion (THD) of the current may exceed 100% [6-8].

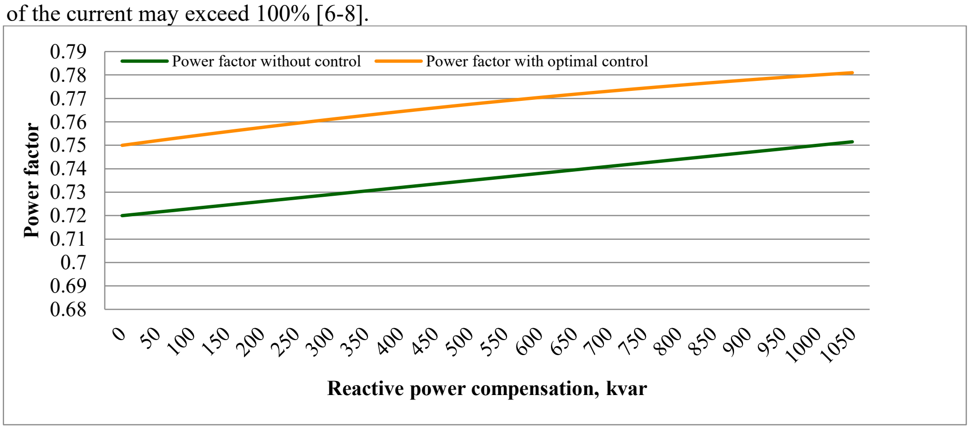

FIGURE 1. Power factor versus reactive power compensation level

EXPERIMENTAL RESEARCH

The conducted analysis indicates that the widespread integration of energy-efficient devices with nonlinear characteristics inevitably leads to an increase in harmonic distortions in current and voltage waveforms. Therefore, energy-saving strategies and measures aimed at improving overall energy efficiency must also incorporate actions that ensure the required power quality and enhance the reliability of electric power supply systems. One of the most effective means for influencing the parameters that determine power quality is the application of specialized compensating equipment-namely, devices designed to filter voltage harmonics. In addition to mitigating harmonic components of current and voltage, such equipment also performs essential auxiliary functions, including reactive power compensation and voltage regulation at bus bars. As a result, they contribute to the stable and reliable operation of electrical networks [9-11].

Active harmonic filters serve as an alternative to passive compensation devices. These systems represent switching-based power-electronic equipment whose operational characteristics are formed through a dedicated control algorithm. Due to their dynamically adjustable behavior, active filters are capable of identifying, generating, and injecting compensating currents in real time, thereby ensuring accurate cancellation of harmonic components within the network.

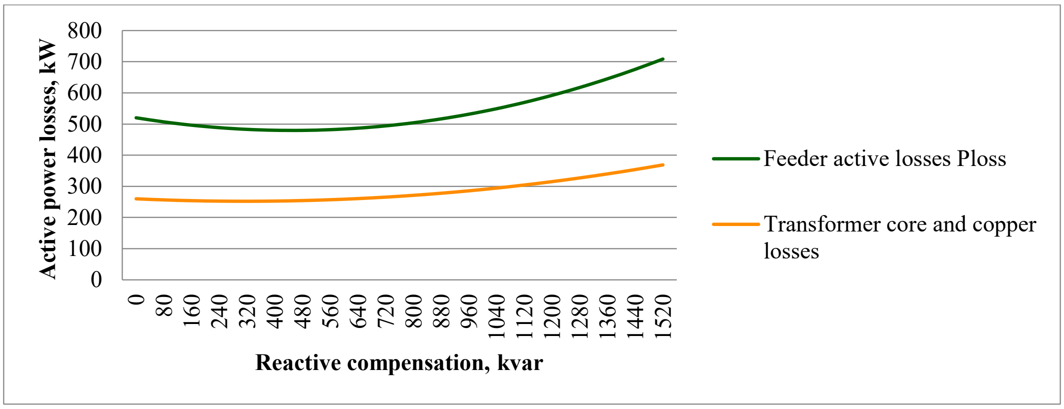

FIGURE 2. Active power losses versus reactive power compensation

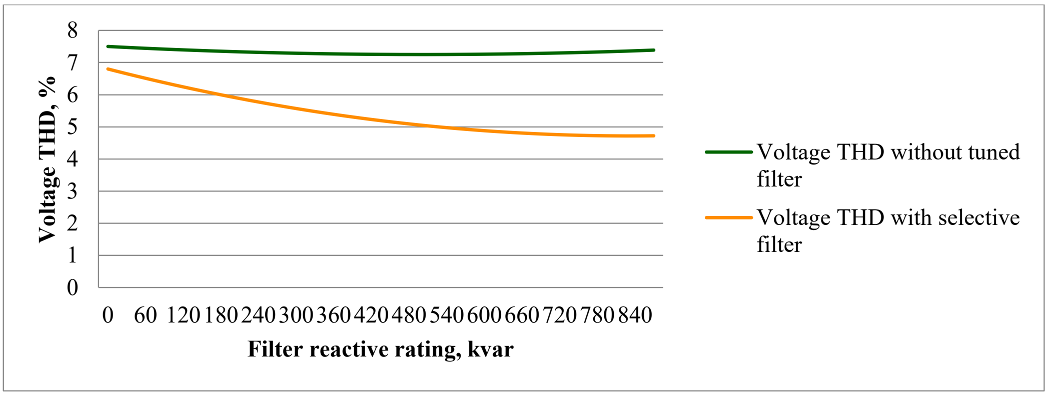

FIGURE 3. Voltage THD versus filter reactive rating

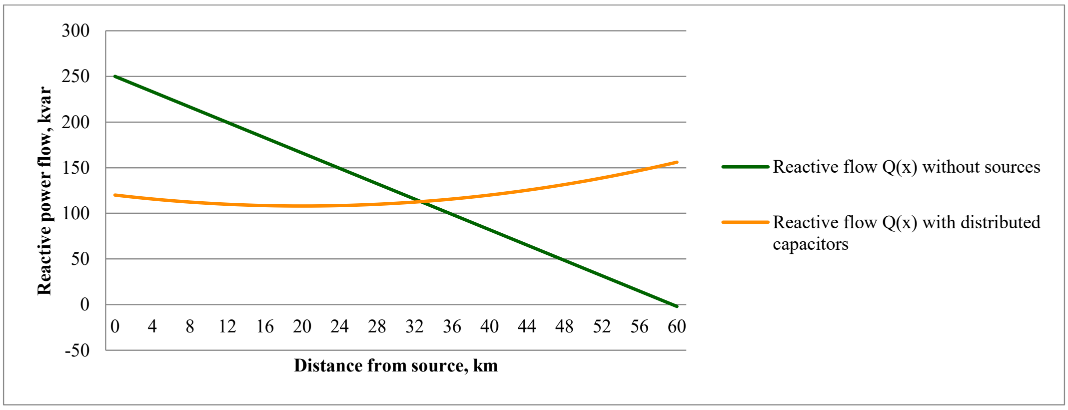

FIGURE 4. Reactive power flow along the distribution feeder

RESEARCH RESULTS

A comparative analysis of the main types of filtering and compensation devices has been carried out. The results show that the most promising solution for controlling power quality in distribution networks is the use of voltage-source hybrid filters, as they combine the advantages of both active and passive filtering technologies. At the same time, the rated power of the active component in a hybrid structure is significantly lower than the power required for a standalone active filter, which ensures higher efficiency, reduced cost, and improved operational stability of the compensation system [12-15].

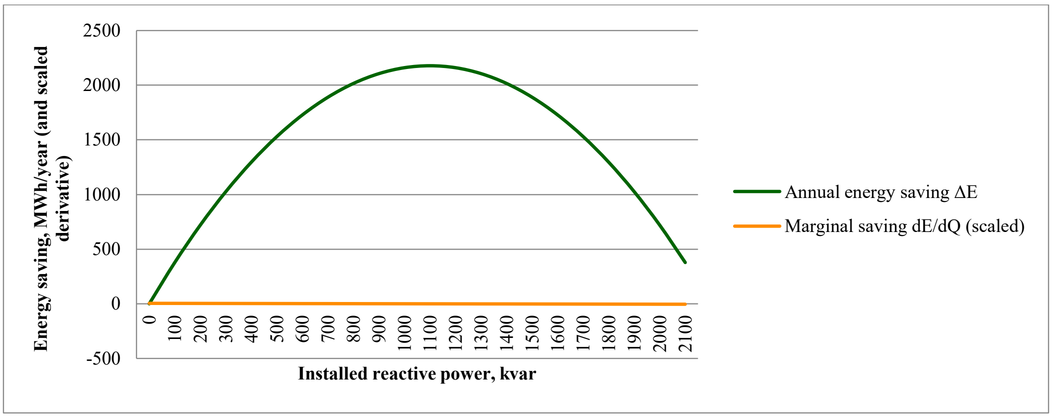

FIGURE 5. Annual energy saving versus installed reactive compensation

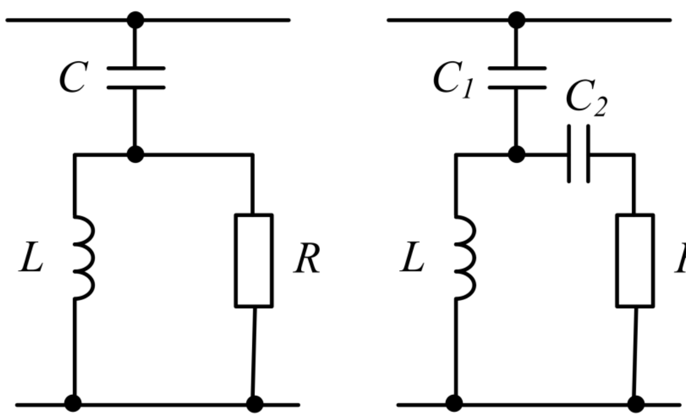

FIGURE 6. Second and third order wie-band filter

The existing design methodologies for passive filters are mainly based on calculating the parameters of series-resonant branches tuned to specific harmonic frequencies. In such approaches, each resonant branch corresponds to an individual harmonic component of the filter, enabling selective attenuation or suppression of the targeted harmonic orders. These methods allow effective control of frequency characteristics only at the resonance frequencies of the parallel network configuration. However, a multi-branch filter represents a complex resonant structure in which the mutual interaction between individual filter sections and the external network impedance must be taken into account. Each branch of the filter forms a parallel resonant circuit with the inductive properties of the supply network. Under real operating conditions, the harmonic spectra of non-sinusoidal currents produced by power-electronic converters often deviate from canonical forms and may contain non-standard or non-integer harmonic components [16-18].

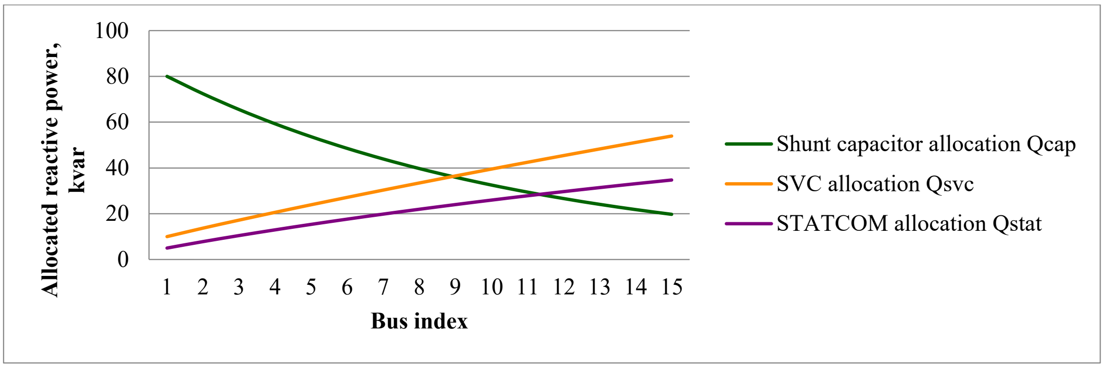

FIGURE 7. Optimal reactive power allocation among devices along the feeder

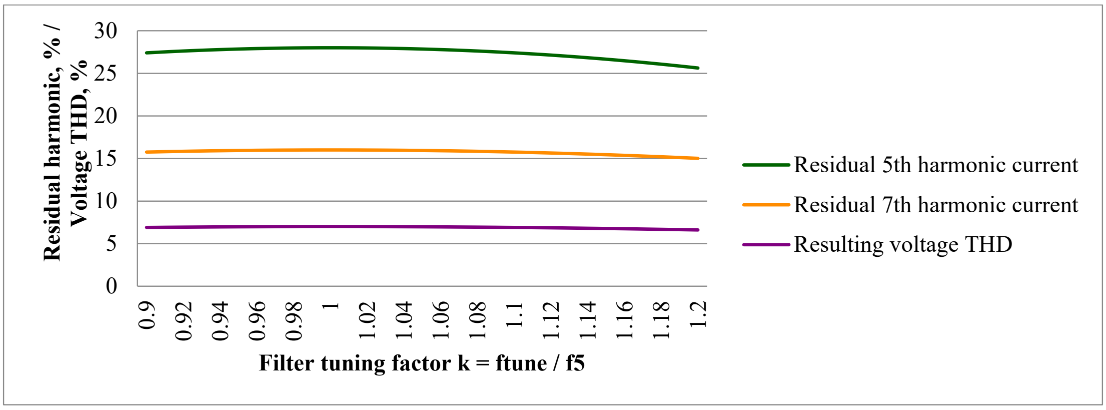

FIGURE 8. Harmonic mitigation versus filter tuning factor

The input impedance of wide-band filters at the fundamental harmonic frequency must be shaped such that the filter can generate the required amount of reactive power. At the same time, the input impedance must remain minimal when connected to a weak distribution line. To simultaneously satisfy both conditions, the frequency characteristics of the input impedance and input admittance should approximate a rectangular-type profile. Existing passive filter design methodologies are primarily based on calculating the parameters of series-resonant branches tuned to specific harmonic frequencies. In these methods, each resonant branch corresponds to a particular harmonic order, thereby enabling the attenuation or elimination of the targeted harmonic components. Such approaches, however, allow control only over the frequency characteristics at the resonance frequencies of parallel networks. In practice, a filter consisting of multiple resonant branches represents a coupled resonant system in which the mutual interaction between the impedances of the filter branches and the external power network must be taken into account. Each individual branch of the filter forms a parallel resonant circuit with the system inductance. Under real operating conditions, the current spectra produced by power electronic converters may contain no canonical or nonstandard harmonic components, deviating from idealized sinusoidal waveforms [19-23].

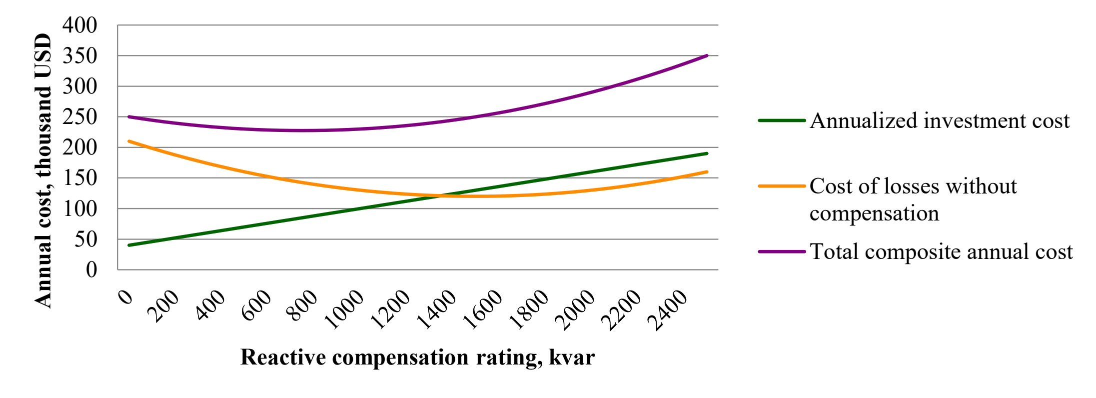

FIGURE 8. Composite annual cost versus reactive compensation rating

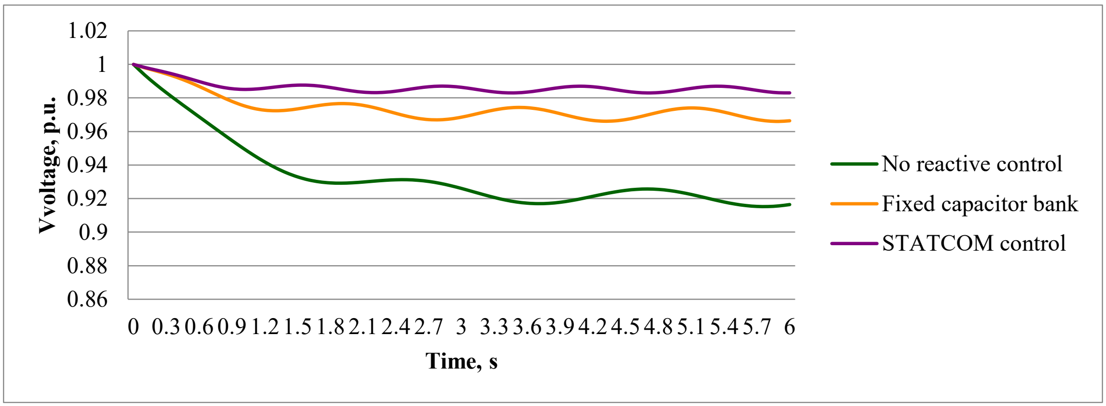

FIGURE 9. Dynamic voltage response under different reactive power controls

The installation of a filter-compensation device must lead to a reduction in the magnitude of higher-order harmonics present in the network current spectrum and ensure a shift reduction in the phase relationship between voltage and current at the fundamental frequency. A passive filter must be designed for the 3rd, 5th, and 11th harmonic components for installation in a 0.38 kV distribution network. The load is an outdoor lighting system equipped with compensated DRL-type lamps, with a total apparent power of 40 kVA. Power supply to the load is provided through a 2 km overhead distribution line. The line is implemented using four-core self-supporting insulated conductors with a cross-sectional area of 35 mm². The calculation is carried out in two consecutive stages. In the first stage, the filter's equivalent (operator) impedance parameters are determined using optimization-based methods [24-53]. These parameters must ensure the required amount of reactive power at the fundamental frequency while simultaneously minimizing harmonic distortion of the current injected into the upstream network. Applying the optimization procedure made it possible to reduce the harmonic distortion factor in the network from 9.6% to 8.1%. To suppress higher-order harmonic components more effectively, the third stage-originally tuned to the 11th harmonic-may be replaced with a wide-band filter section having the same reactive power rating as the narrow-band unit. This solution provides enhanced attenuation across a broader frequency interval and improves the mitigation of non-characteristic high-frequency harmonics, thereby contributing to the overall improvement of power quality in the 0.38 kV distribution network.

TABLE 2. The harmonic–spectral components of the supply current

Configuration option	I_1, A	I_3, A	I_5, A	I_7, A	I_{11}, A	K_I, %
Compensation before filter installation	57.92	13.88	7.03	5.34	4.16	29.30
Post-filter compensation mode	59.02	3.76	1.22	4.01	1.81	9.63
Capacitance-optimized filter	59.02	2.07	1.26	4.06	1.57	8.09
Broad-band harmonic filter	59.02	2.07	1.26	5.39	2.37	10.08

For designing the filter-compensation unit, the software tools discussed in Section 4.1 were used. The developed device simultaneously performs reactive power compensation at the fundamental harmonic frequency and filtering of higher-order harmonics. Depending on the operating mode of the drilling equipment, the magnitude of the consumed power varies significantly, which leads to voltage fluctuations. Frequent voltage rises may cause damage to capacitor banks. For rapidly varying loads typical of drilling units, dynamic compensation of reactive power may be required to stabilize the supply voltage. Since the passive harmonic filter is a static device, it is advisable to incorporate a shunt reactor into the filter-compensation unit to control the amount of generated reactive power. Because the filter exhibits capacitive reactance at the fundamental frequency, the excess reactive power produced by the filter is compensated by the reactor's reactive power.

CONCLUSIONS

A set of power-quality problems inherent in distribution networks with various consumer categories has been examined. One of the dominant factors contributing to the degradation of power-supply quality is the widespread use of energy-saving devices that exhibit nonlinear electrical characteristics. To ensure compliance with power-quality requirements, it becomes essential to employ adaptive multifunctional compensation devices capable of regulating reactive power, reducing current and voltage harmonic distortion, and maintaining other quality indices within normative limits. A computational methodology for passive filter-compensation systems has been developed. The approach is based on minimizing a target function defined in the space of operator input impedance parameters of the filter. The design variables consist of the operator impedance poles and their corresponding normalization coefficients. By applying synthesis-based tuning techniques, the filter–compensation unit can be regarded as a complex resonant system in which the mutual electromagnetic interaction between the internal filter branches and the external network is explicitly taken into account. The proposed method makes it possible to design minimum-order passive filter-compensation devices that simultaneously provide reactive-power compensation, attenuation of no canonical odd harmonics, and suppression of abnormal spectral components. Furthermore, a calculation method for hybrid filter–compensation systems has been proposed. This method performs optimization of device characteristics in a combined parameter space that includes both passive-filter elements and active-filter control parameters. The resulting hybrid system provides effective reactive-power compensation and ensures the suppression of harmonic currents and voltages generated by nonlinear loads as well as those introduced from the upstream network. The developed methodologies for passive and hybrid filter–compensation system design have been implemented in specialized interactive software for optimal synthesis. Using this software, filter–compensation devices have been designed for consumers with a high level of nonlinear load, ensuring improved power quality and compliance with electrical-energy standards.

REFERENCES

1. Asliddin Norqulov, Feruz Raximov, Methods for evaluating financial and economic effectiveness of investment projects in the energy sector with time factor considerations, AIP Conf. Proc. **3331,** 030070-1–030070-6. https://doi.org/10.1063/5.0306104
2. 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
3. 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

4. Abdurakhim Taslimov., Feruz Raximov., Farrukh Rakhimov., Iles Bakhadirov, Optimal parameters and selection criteria for neutral grounding resistors in 20 kv electrical networks, AIP Conf. Proc. **3331**, 030048 (2025) https://doi.org/10.1063/5.0306108
5. 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
6. 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
7. Numon Niyozov, Anvar Akhmedov, Shukhrat Djurayev, Botir Tukhtamishev, Asliddin Norqulov, Development of a method for forecasting the specific consumption indicator of electric energy, AIP Conf. Proc. **3331,** 080008 (2025) https://doi.org/10.1063/5.0305729
8. Bakhodir Ramazonov, Shakhzodbek Sayfiev, Khasan Muradov, Mathematical modeling and research of high capacity lead-acid stabilized accumulator battery, AIP Conf. Proc. **3268,** 020043 (2025) https://doi.org/10.1063/5.0257860
9. Khasan Murodov, Askarbek Karshibayev, and Shukhrat 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
10. Muzaffar Xolmurodov., Shaxzod Hakimov., Umida Oripova, Improving energy efficiency in public buildings: Modern technologies and methods, AIP Conf. Proc. **3331,** 040060 (2025) https://doi.org/10.1063/5.0306935
11. Shirinov S.G., J.S. Olimov, I.Z. Jumayev, M.K. Sayidov Analysis of patterns of electricity consumption in mining and processing enterprises. Vibroeng. Procedia 2024, **54,** 308–313. https://doi.org/10.21595/vp.2024.24073
12. Jumayev, Z.I., Karshibayev, A.I., Sayidov, M.K., & Shirinov, S.G. Analysis of climate-meteorological and technological factors affecting electricity consumption of mining enterprises. Vibroengineering Procedia, Vol. **54,** pp. 293-299 (Apr. 4 2024). https://doi.org/10.21595/vp.2024.24047
13. 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
14. 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
15. 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
16. 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
17. I.Togayev, A.Tovbaev, 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
18. 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
19. Sulton Amirov, Aminjon Ataullayev, Sine-cosine rotating transformers in zenith angle converters, E3S Web of Conferences **525,** 03010 (2024) GEOTECH-2024, https://doi.org/10.1051/e3sconf/202452503010
20. Sultan F. Amirov, Nodir O. Ataullayev, Amin O. Ataullayev, Bobur Q. Muxammadov, and Ahror U. Majidov, Methods for reducing the temperature components of magnetomodulation DC convertors errors, E3S Web of Conferences **417,** 03011 (2023) GEOTECH-2023 https://doi.org/10.1051/e3sconf/202341703011
21. Boboqulov J., Narzullayev B, Development of a model for diagnosing rotor conditions in the parallel connection of synchronous generators with the network, E3S Web of Conferences. – EDP Sciences, 2024. – **T. 525**. – C. 06001. https://doi.org/10.1051/e3sconf/202452506001
22. Narzullayev B. S., Eshmirzaev M. A, Causes of the appearance of current waves in high voltage electric arc furnaces, and methods of their reduction, E3S Web of Conferences. – EDP Sciences, 2023. – **T. 417**. – C. 03003. https://doi.org/10.1051/e3sconf/202341703003
23. 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

24. Urishev, B., and Fakhriddin Nosirov. 2025. "Hydraulic Energy Storage of Wind Power Plants." Proceedings of the International Conference on Applied Innovation in IT.
25. 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.
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. 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
30. 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
31. 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
32. 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
33. 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
34. 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
35. 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
36. 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
37. 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
38. 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
39. 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
40. 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
41. 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

42. 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
43. 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.
44. 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.
45. 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
46. 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
47. 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
48. 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
49. 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
50. 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
51. 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
52. 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
53. 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