V International Scientific and Technical Conference Actual Issues of Power Supply Systems

Maintaining the balance of the electric energy ridge through high-power hybrid energy storage ridges

AIPCP25-CF-ICAIPSS2025-00362 | Article

Maintaining the balance of the electric energy ridge through high-power hybrid energy storage ridges.

Khasan Murodov[1,a)], Askarbek Karshibayev[1], Zavqiyor Jumayev[1], Shuxratbek Mannobboyev

[1] *Navoi State University of Mining and Technology, Navoi, Uzbekistan*
[2] *Andijan State Technical Institute, Andijan, Uzbekistan*

[a)] *Corresponding author:* murodov.xasan@inbox.ru

Abstract. The article presents an analysis of the combined use of high-power hybrid electric energy storage stationary electric chemical batteries and supercapacitors and the stabilization of the balance of the electric energy range. Also listed are the characteristics of stationary hybrid accumulators. The current state-of-the-art various chemical electric energy storage lead-acid accumulator, supercapacitor and simple capacitor parameters are given comparative characteristics. Characteristics of lead-acid battery batteries and supercapacitors discharge and discharge are presented. With the help of battery batteries and supercapacitors, a model construction of a hybrid energy storage system was built, and through this device the characteristics of which depend on the power of the current forces were obtained and analyzed.

INTRODUCTION

Currently, the issue of efficient storage and distribution of electricity is becoming more important in transport, renewable energy systems and telecommunication infrastructures. One of the most widely used energy storage devices is lead — acid batteries, which are significant for their low cost and reliability. However, their main disadvantage is that low energy density and fast operation are degraded in deep cycles. At the same time, supercapacitors are characterized by a very high energy density, resistance to millions of charging-discharge cycles and the possibility of providing fast electricity. But their energy density is lower than that of conventional batteries. Therefore, it can be a reliable, high-quality battery with a longer service life, which is more resistant if a lead-acid battery and supercapacitors are jointly developed as a hybrid electric energy storage system in a state suitable for today [1]. Electricity consumers the character of the energy system is sharply variable, which at such times negatively affects the dynamic stagnation of electricity-generating sources in the energy range. In this case, a sharp change in voltage will be able to disrupt sensitive equipment. In this, especially pulsed and sharply variable loads are caused by the launch of high-power engines, induction, arc furnaces and similar devices. At times of low night load, the value of electricity generated in thermal power plants is not possible to change in large quantities, but it is observed that the voltage in power lines exceeds the established nominal values [2-4].

In today's world, electrical chemical electrical energy storage systems are used to prevent these problems. But a sharp change in the load is reducing the life of battery batteries due to the fact that the discharge current exceeds the maximum. However, the use of electrical chemical preservatives in conjunction with supercapacitors prevents such problems [5].

Electrical chemical energy harvesting constructions are applied to collect and repel energy chemically. They are called galvanic elements or battery batteries. These types of energy harvesting devices are the most common. There is also a lot of work being done in the world to increase the service life of these devices.

Superconductors, or so-called ignitors, are used in large-speed collection and transmission of electricity in construction. It is seen as an alternative to conventional electric chemical accumulators, which, through this feature, began to be widely used in the automotive industry.

Such an advantage of supercapacitors is explained by their structure and the mechanism of energy collection. The supercapacitor consists of two electrodes immersed in an electrolyte, and between them there is a separator separating the liquid. The Separator prevents the direct exchange of charge between the cathode and the anode. Energy accumulation occurs through an electrostatic charge-a double layer of electricity — that forms on two opposite surfaces adjacent to the electrodes an advantage of supercapacitors is explained by their structure and the m.

During the charging process, the electrolyte ions irregularly tend to the opposite charged electrode surface. This process is fully reversible, resulting in superconductors having high power, long service life, energy storage duration, and simplicity of maintenance.

Supercapacitors are characterized by a much larger capacity compared to conventional electric chemical batteries, and a higher energy capacity compared to ordinary capacitors. Currently, lithium-ion accumulators can return between 70% and 95% of the energy they receive, compared to 85% to 99% in supercapacitors.

In addition, while battery batteries tend to reduce capacity after several hundred discharge cycles, ionistors can operate for millions of cycles almost without loss of capacity.

In this case, a comparison of the characteristics of their capacitor, supercapacitor and battery batteries

Shown from Table 1 [6].

Table 1. Comparison of capacitor, supercapacitor and battery characteristics

Description	**Capacitor**	**Supercapacitor**	**storage batteries**
of the type	al, ta oxide	Acute C, H2SO4, TEABF4/AC, PC,	Pb-Ac To cd-rom, Select-MH, li-ion
Charge collection method	Electrostatic	Electrostatic	Electric chemical
E (W·hr/kg)	<0.1	1-10	20-200
P, (w/kg)	>>10000	500-10000	200-5000
Discharge Full time	10^{-6} – s 10-3	s 1-60	5 min – 5 hours
fully charged time: up to	10^{-6} – s 10-3	s 1-60	10 min – 10 hours
Discharge effectiveness	1,0	0,85–0,99	of 0.7–0,95
full of the number of cycles, n	>>10^6	>10^6	103 – 5·103
rated voltage U (V)	High	of 2.3 – to 2.7	to 3.2 – 3.7
Charge to store the index	Low	Low	High
charged to line up the shape of the curve	Linear	Linear	Flat
temperature range	from -60 to 125°c	-40 to 65°C	from -40 to 60°c (discharge) / from 0 to 45°c (charging test)
1 kw·hour price	>1 000 000 $	>10 000 $	250 $ – 1000 $

To charge, you need to have on hand:
- the nominal charge of the battery when charging;
-the degree of pulsation of alternating current and battery charge;
- parallel universe;
- rechargeable battery to control the entire circuit;
- increase the battery capacity;
-in case of emergency shutdown of the battery, up to 90% of the charge level is maintained.;
- battery charging current limit;
-loading is done with a trigger.

Comparison of capacitive rechargeable batteries or capacitors used in the assembly of a supercapacitor charge, determination of the main parameters of the charge and discharge of batteries all cells have the same length and width. The differentiation of supercapacitors from conventional accumulators is also observed in the description of charge–discharge curves. In supercapacitors, this curve will have a constant slope, in accumulators the charge–discharge form will have a nonlinear form with a horizontal area. This can be seen in Figures 1 and 2.

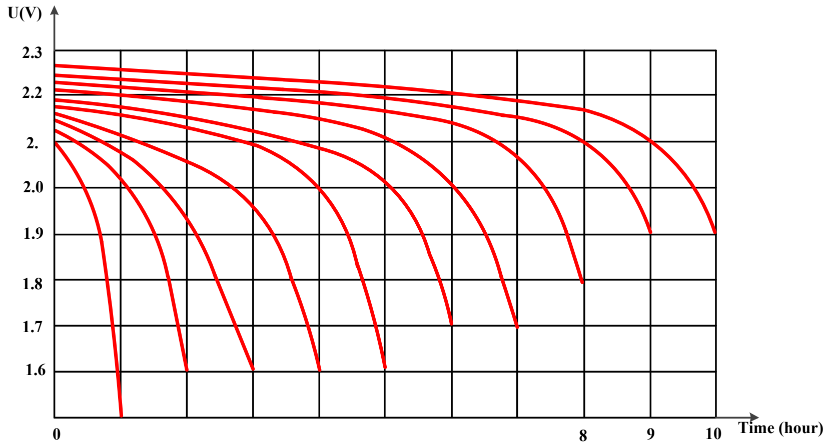

FIGURE 1. Hermetic lead is a discharge characteristic of an acid battery.

From the discharge characteristic of hermetic type lead acid battery batteries, it can be seen that rapid discharge at different voltages reduces their active capacity and also reduces the service life shrinks. In this case, with the sequestration of the start time of discharge, there will be a significant storage capacity for their charge capture.

The charge characteristic of supercapacitors will have a linear incidence. Their charge characteristic is shown in Figure 2, with the voltage being a linear smooth riser and the current strength being constant over time.

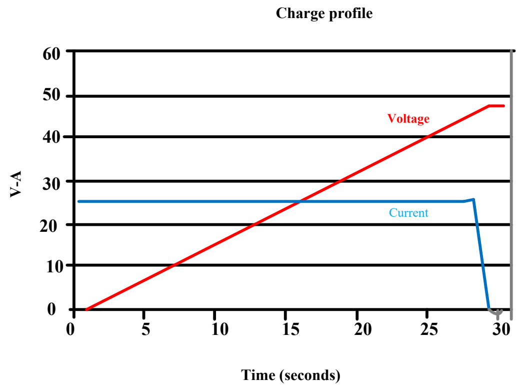

FIGURE 2. Supercapacitor charging characteristics.

The joint use of battery batteries with supercapacitors reduces the damage to accumulators for peak States of the electrical energy system. Their performance cycles are not adversely affected [7].

Currently, in the power supply systems of enterprises, power transformers operate in an unloaded mode, which leads to an increase in idle losses [8]. Even at this time, electricity creates the need to use the nergy storage Ridge.

EXPERIMENTAL RESEARCH

A device was developed with the aim of researching hybrid energy storage systems consisting of supercapacitors and electrical chemical energy harvesting devices. This device is based on the study of the modes of operation of the hybrid energy storage system in different load types and their values.

With the joint application of supercapacitor and battery batteries, a hybrid energy storage system is equipped. A system with a sharply variable consumer load through a hybrid electric energy storage system we will build a model

and test as an experiment how the hybrid energy storage system behaves in this system. In doing so, we build the experimental device model shown in Figure 3 below.

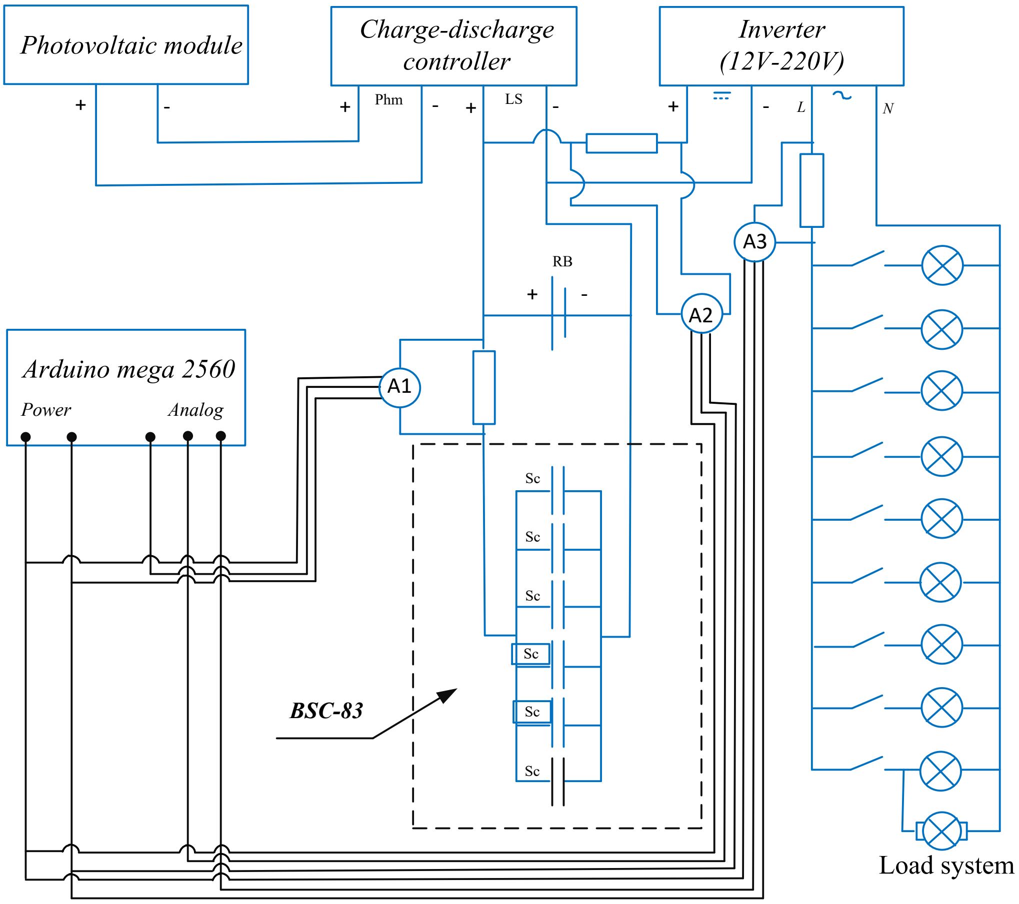

FIGURE 3. Schematic diagram of the experimental setup.

As can be seen from the picture, the device consists of two parts: a 12-V fixed current and a 220-V variable current part. In the variable current section there is a loading location, that is, an engine and spark plugs. This part loading was done with a pulsed engine and lights were installed as static loading [23-52].

The fixed current section houses BSC-83, a lead-acid battery, inverter and control unit. When collecting electricity, a control device is installed to control the charging system. A solar panel is used to generate electricity, or other 12 V sources can also be used[9-10,11,12]

The device uses current sensors to measure the current forces flowing through the networks.

This device can simulate 4 modes:

- charging hybrid energy system;
- discharge of the electrical chemical Enegia collection system in a sharp change and in a static state;
- superconducting discharge in a sharp change and in a static state. The device uses current sensors to measure the current forces flowing througte [13-14,15,16]

RESEARCH RESULTS

In the case of low load in the electrical energy system, the charge of the hybrid system and its load are subject to a sharp change, as well as research on the power and current strength of the hybrid system in the case of discharge at the time of increasing load. In this case, kamani is studied in pulsed and sharply variable cases. In the first case, we observe the variation of the discharge token in accordance with the load capacity the case of low load in the electrical energy system, the charge of the hybrid system and its load are subject to a shar.

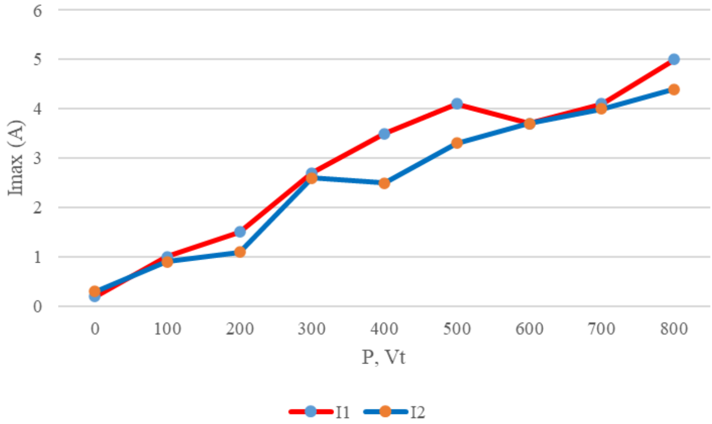

FIGURE 4. Graph of the dependence of the hybrid system current and load current on the load power.

The i1 value of the hybrid system current changes to the load current i2 with a nonlinear bond i.e. with an increase in power, the load current does not match the value of i2. In the graph obtained according to the results of the analysis, discharge with an increase in the load current to the maximum leads to an increase in the current of the supercapacitor. At a small value, loading receives energy from the electrical chemical energy storage system. However, when the load current reaches its maximum i.e. during a sharp load change and in pulsed cases, battery batteries cannot be maximally discharged, and in this case, the superconductor receives energy from the energy storage system at peak times. We can see this from Figure 5 of the power dependence graph of the supercapacitor and battery batteries below [17-18,19].

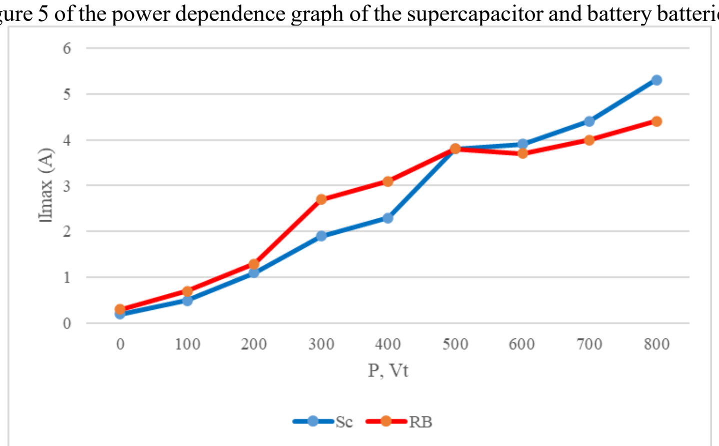

FIGURE 5. Graph of current strength versus power for supercapacitor and battery cells.

Based on the results of the analysis of the resulting graph, the accumulator current is the main source in the initial case. As the load token increases, the supercompensation current begins to rise. In this case, the load current protects the battery from a large discharge current in cases of increased load [20-22].

CONCLUSIONS

The results of the study showed that in the current electrical energy system, there is no possibility to change the power of the existing electric power generating thermal eleter stations in large quantities. The electric energy range requires extensive consideration of the ability to collect electricity at low load times through energy storage systems, as well as the ability to extract energy from the energy storage range at a time when the load has increased dramatically. Also as energy storage systems, electrical chemical methods are currently being used. But this made it possible that the batteries were not resistant to sharp and pulsed changes in the loading value. Therefore, the need for the application of hybrid ridges, which work in accordance with the drastic changes in loading, as well as the development of automatic ridges, which effectively control them, increases.

REFERENCES

1. Khasan Murodov, Askarbek Karshibayev, and Shukhrat Abdullayev. E3S Web of Conferences 548, 03012 (2024) https://doi.org/10.1051/e3sconf/202454803012
2. Bakhodir Ramazonov; Shakhzodbek Sayfiev; Khasan Muradov. Mathematical modeling and research of high capacity leadacid stabilized accumulator battery // *AIP Conf. Proc.* 3268, 020043 (2025) https://doi.org/10.1063/5.0257860
3. 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
4. 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
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. Nikita Sergeevich Romanyuk, Alexey Gennadievich Vaskov, Ksenia Alexandrovna Andreeva, Anastasia Alekseevna Vasilyeva. Research of hybrid energy storage systems based on supercapacitors // Journal "Environment and Energy Science" (OSE) No. 4(2024) DOI: 10.24412/2658-6703-2024-4-103-114
7. 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.
8. 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
9. 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
10. 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
11. 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
12. 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
13. 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
14. Olimov, J. S., Fayziyev, S. S., Raximov, F. M., Majidov, A. U., & Muxammadov, B. Q. (2023). Controlling power of short circuited induction motor via modern sensors without speed change. In E3S Web of Conferences (Vol. 417, p. 03007). EDP Sciences. https://doi.org/10.1051/e3sconf/202341703007
15. Rakhimov, F., Rakhimov, F., Samiev, S., & Abdukhalilov, D. (2024, June). Justification of technical and economic effectiveness of application of 20 kV voltage in overhead electric networks. In AIP Conference Proceedings (Vol. 3152, No. 1, p. 030023). AIP Publishing LLC. https://doi.org/10.1063/5.0218921
16. 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
17. 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

18. 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
19. Eshmurodov, Z., Bobojanov, M., & Abdullaev, S. (2025, November). Investigation of factors affecting the efficiency of mining transport systems. In *AIP Conference Proceedings* (Vol. 3331, No. 1, p. 040013). AIP Publishing LLC. https://doi.org/10.1063/5.0306591
20. Eshmurodov, Z., & Abdullaev, S. (2024). Investigation of the methods of starting and braking in the "Frequency converter asynchronous motor" system. In E3S Web of Conferences (Vol. 548, p. 06013). EDP Sciences. https://doi.org/10.1051/e3sconf/202454806013
21. Ataullaev, A. O., & Sayidov, M. K. (2023). Investigation of multi loop linear magnetic circuits of electromagnetic flow converters with ring channels. In *E3S Web of Conferences* (Vol. 417, p. 03006). EDP Sciences. https://doi.org/10.1051/e3sconf/202341703006
22. Khudayarov, M., Makhmudov, T., & Fayziyev, S. (2025, November). Tuning hyperparameters of artificial neural networks to solve problems of calculating steady-state modes and electricity losses in distribution networks. In *AIP Conference Proceedings* (Vol. 3331, No. 1, p. 030066). AIP Publishing LLC. https://doi.org/10.1063/5.0305698
23. Melikuziev M.V., Fayzrakhmanova Z., Akhmedov A., Kasimova G. Development of an Educational Simulator's Working Logic for the Course 'Fundamentals of Power Supply'. AIP Conference Proceedings 3152, 050025 (2024). https://doi.org/10.1063/5.0218875
24. Melikuziev M.V., Nematov L.A., Novikov A.N., Baymuratov K.K. Technical and economic analysis of parameters of city distribution electric network up to 1000 V. E3S Web of Conferences 289, 07016 (2021) Energy Systems Research. https://doi.org/10.1051/e3sconf/202128907016
25. L.Jing, J.Guo, T.Feng, L.Han, Z.Zhou and M.Melikuziev, "Research on Energy Optimization Scheduling Methods for Systems with Multiple Microgrids in Urban Areas," 2024 IEEE 4th International Conference on Digital Twins and Parallel Intelligence (DTPI), Wuhan, China, 2024, pp. 706-711, https://ieeexplore.ieee.org/abstract/document/10778839
26. Shukhrat Umarov, Murot Tulyaganov. Peculiarities of simulation of steady modes of valve converters with periodic power circuit structure. III International Scientific and Technical Conference "Actual Issues of Power Supply Systems" (ICAIPSS2023). AIP Conf. Proc. 3152, 050004-1–050004-7; https://doi.org/10.1063/5.0218869
27. Murot Tulyaganov, Shukhrat Umarov. Improving the energy and operational efficiency of an asynchronous electric drive. III International Scientific and Technical Conference "Actual Issues of Power Supply Systems" (ICAIPSS2023); https://doi.org/10.1063/5.0218876
28. Shukhrat Umarov, Khushnud Sapaev, Islambek Abdullabekov. The Implicit Formulas of Numerical Integration Digital Models of Nonlinear Transformers. AIP Conf. Proc. 3331, 030105 (2025); https://doi.org/10.1063/5.0305793
29. Shukhrat Umarov, Murat Tulyaganov, Saidamir Oripov, Ubaydulla Boqijonov. Using a modified laplace transform to simulate valve converters with periodic topology. AIP Conf. Proc. 3331, 030104 (2025); https://doi.org/10.1063/5.0305792
30. Murat Tulyaganov, Shukhrat Umarov, Islambek Abdullabekov, Shakhnoza Sobirova. Optimization of modes of an asynchronous electric drive. AIP Conf. Proc. 3331, 030084 (2025); https://doi.org/10.1063/5.0305786
31. Islombek Abdullabekov, Murakam Mirsaidov, Shukhrat Umarov, Murot Tulyaganov, Saidamirkhon Oripov. Optimizing energy efficiency in water pumping stations: A case study of the Chilonzor water distribution facility; AIP Conf. Proc. 3331, 030107 (2025); https://doi.org/10.1063/5.0305780
32. Kobilov, N., Khamidov, B., Rakhmatov, K., Abdukarimov, M., Daminov, O., Shukurov, A., Kodirov, S., Omonov, S. Investigation and study of oil sludge of oil refinery company in Uzbekistan. AIP Conference Proceedings, 3304, **040076**, (2025), https://doi.org/10.1063/5.0269039
33. Kobilov, N., Khamidov, B., Rakhmatov, K., Daminov, O., Ganieva, S., Shukurov, A., Kodirov, S., Omonov, S. Development of effective chemicals for drilling fluid based on local and raw materials of Uzbekistan. AIP Conference Proceedings, 3304, **040077**, (2025), https://doi.org/10.1063/5.0269403
34. Umerov, F., Daminov, O., Khakimov, J., Yangibaev, A., Asanov, S. Validation of performance indicators and theoretical aspects of the use of compressed natural gas (CNG) equipment as a main energy supply source on turbocharged internal combustion engines vehicles. AIP Conference Proceedings, 3152, **030017**, (2024), https://doi.org/10.1063/5.0219381
35. Matmurodov, F.M., Daminov, O.O., Sobirov, B.Sh., Abdurakxmanova, M.M., Atakhanov, F.U.M. Dynamic simulation of force loading of drives of mobile power facilities with variable external resistance. E3s Web of Conferences, 486, **03001**, (2024), https://doi.org/10.1051/e3sconf/202448603001

36. Musabekov, Z., Daminov, O., Ismatov, A. Structural solutions of the supercharged engine in the output and input system. E3s Web of Conferences, 419, **01015**, (2023), https://doi.org/10.1051/e3sconf/202341901015
37. Musabekov, Z., Ergashev, B., Daminov, O., Khushnaev O., Kurbanov, A., Kukharonok, G. Efficiency and environmental indicators of diesel engine operation when using water injection. IOP Conference Series Earth and Environmental Science, 1142, **012024**, (2023), https://doi.org/10.1088/1755-1315/1142/1/012024
38. Tulaev, B.R., Musabekov, Z.E., Daminov, O.O., Khakimov, J.O. Application of Supercharged to Internal Combustion Engines and Increase Efficiency in Achieving High Environmental Standards. AIP Conference Proceedings, 2432, **030012**, (2022), https://doi.org/ 10.1063/5.0090304
39. Matmurodov, F., Yunusov, B., Khakimov, J., Daminov, O., Gapurov, B. Mathematical Modeling and Numerical Determination of Kinetic and Power Parameters of Loaded Power Mechanisms of a Combined Machine. AIP Conference Proceedings, 2432, **040013**, (2022), https://doi.org/ 10.1063/5.0090304
40. Ma'ruf, K., Tursoat, A., Dilnavoz, K., Bekmurodjon, R., Ra'no, A., Saida, T., ... & Toshbekov, B. (2025). ZnO Nanoparticles Incorporated on Multi-Walled Carbon Nanotubes as A Robust Heterogeneous Nano-catalyst for Biodiesel Production from Oil. Journal of Nanostructures, 15(3), 1050-1060.
41. Safarov J., Khujakulov A., Sultanova Sh., Khujakulov U., Sunil Verma. Research on energy efficient kinetics of drying raw material. // E3S Web of Conferences: Rudenko International Conference "Methodological problems in reliability study of large energy systems" (RSES 2020). Vol. 216, 2020. P.1-5. doi.org/10.1051/e3sconf/202021601093
42. Safarov J., Sultanova Sh., Dadayev G.T., Zulponov Sh.U. Influence of the structure of coolant flows on the temperature profile by phases in a water heating dryer. // IOP Conf. Series: Materials Science and Engineering. Dynamics of Technical Systems (DTS 2020). Vol.1029, 2021. №012019. P.1-11. doi:10.1088/1757-899X/1029/1/012019
43. Sultanova Sh.A., Artikov A.A., Masharipova Z.A., Abhijit Tarawade, Safarov J.E. Results of experiments conducted in a helio water heating convective drying plant. // International conference AEGIS-2021 «Agricultural Engineering and Green Infrastructure Solutions». IOP Conf. Series: Earth and Environmental Science 868 (2021) 012045. P.1-6. doi:10.1088/1755-1315/868/1/012045
44. Sultanova Sh., Safarov J., Usenov A., Samandarov D., Azimov T. Ultrasonic extraction and determination of flavonoids. XVII International scientific-technical conference "Dynamics of technical systems" (DTS-2021). AIP Conference Proceedings 2507, 050005. 2023. P.1-5. doi.org/10.1063/5.0110524
45. Saparov Dj.E., Sultonova S.A., Guven E.C., Samandarov D.I., Rakhimov A.M. Theoretical study of characteristics and mathematical model of convective drying of foods. // RSES 2023. E3S Web of Conferences 461, 01057 (2023). P.1-5. https://doi.org/10.1051/e3sconf/202346101057
46. Safarov J.E., Sultanova Sh.A., Dadayev G.T., Samandarov D.I. Method for drying fruits of rose hips. // International Journal of Innovative Technology and Exploring Engineering (Scopus). Volume-9, Issue-1, November, 2019. P.3765-3768. doi: 10.35940/ijitee.A4716.119119
47. Safarov J.E., Sultanova Sh.A., Dadayev G.T., Samandarov D.I. Method for the primary processing of silkworm cocoons (Bombyx mori). // International Journal of Innovative Technology and Exploring Engineering (Scopus). Volume-9, Issue-1, November, 2019. P.4562-4565. DOI: 10.35940/ijitee.A5089.119119
48. Sultanova Sh., Safarov J., Usenov A., Raxmanova T. Definitions of useful energy and temperature at the outlet of solar collectors. // E3S Web of Conferences: Rudenko International Conference "Methodological problems in reliability study of large energy systems" (RSES 2020). Vol. 216, 2020. P.1-5. doi.org/10.1051/e3sconf/202021601094
49. Usenov A.B., Sultanova Sh.A., Safarov J.E., Azimov A.T. Experimental-statistic modelling of temperature dependence of solubility in the extraction of ocimum basilicum plants. // International conference AEGIS-2021 «Agricultural Engineering and Green Infrastructure Solutions». IOP Conf. Series: Earth and Environmental Science 868 (2021) 012047. P.1-5. doi:10.1088/1755-1315/868/1/012047
50. 1Sultanova Sh.A., Safarov J.E., Usenov A.B., Muminova D. Analysis of the design of ultrasonic electronic generators. // Journal of Physics: Conference Series. International Conference "High-tech and Innovations in Research and Manufacturing" (HIRM 2021). 2176 (2022) 012007. doi:10.1088/1742-6596/2176/1/012007
51. Zulpanov Sh.U., Samandarov D.I., Dadayev G.T., Sultonova S.A., Safarov J.E. Research of the influence of mulberry silkworm cocoon structure on drying kinetics. // IOP Conf. Series: Earth and Environmental Science (AEGIS-2022). 1076 (2022) 012059. P.1-6. doi:10.1088/1755-1315/1076/1/012059
52. Tarawade A., Samandarov D.I., Azimov T.Dj., Sultanova Sh.A., Safarov J.E. Theoretical and experimental study of the drying process of mulberry fruits by infrared radiation. // IOP Conf. Series: Earth and Environmental Science (ETESD). 1112 (2022) 012098. P.1-9. doi:10.1088/1755-1315/1112/1/012098