A Device that Controls the Power Supply Sources of a Mobile Communication Base Station

Davronbekov Dilmurod[1], Matyokubov Utkir[2], and *Muradov Muhammad[3]

[1, 3] Department of Mobile Communication Technologies, Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Tashkent, Uzbekistan
[2] Department of Telecommunication Engineering, Urgench branch of Tashkent University of Information Technologies named after Muhammad al-Khwarizmi, Urgench, Uzbekistan

Correspondence should be addressed to *Muhammad Muradov; muradov.muhammad1414@gmail.com

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ABSTRACT- In this research work, the classifications of the device that controls the energy supply sources of the mobile communication base station are presented. The device is used to automatically control the connection and disconnection of the next power source based on the status of the mobile communication base station power supply sources. This device was tested in real-world conditions at mobile communication base stations in the Khorezm region of the Republic of Uzbekistan, and the results were analyzed. The created device allows for rapid response to outages at base stations, management of supply sources based on their status, and monitoring of them, thereby increasing the reliability of energy supply sources and extending the life of backup energy supply sources.

KEYWORDS- Base Station, Power Supply, Supercapacitor, Battery, Uninterruptible Power Supply, Reliability

I. INTRODUCTION

Currently, four mobile operators provide their services to subscribers in the Khorezm region of the Republic of Uzbekistan. Due to the relatively scattered location of this area, communication operators are expanding communication coverage using modern technologies. Although the high frequency range allows for high-quality and fast services, it reduces the service distance. Therefore, it is necessary to regularly increase the number of base stations to ensure full coverage of mobile communication networks in the regions [1][2][3].

One of the most important factors for the effective operation of mobile communication systems is the uninterrupted and stable supply of power to base stations. Uninterrupted power supply to base stations increases the quality and reliability of network services. Therefore, various studies are being conducted in developed countries aimed at increasing the energy efficiency of mobile communication infrastructure. Such research is aimed at using alternative energy sources, introducing energy-saving technologies, and developing intelligent control systems, which will not only improve communication quality, but also increase the overall efficiency of the network infrastructure [4][5][6].

II. THE MAIN PART

The mobile communication base station can be supplied with electricity through two types of AC and DC power supply sources. AC power sources include local power grids, wind generators, diesel generators, while DC power sources include batteries and solar panels. The parameters of the above energy supply sources are presented in Tables 1 and table 2. Maintaining the parameters of the electricity supplied by the power supply sources within the limits in this table increases the reliability of the base station power supply system and reduces the number of outages. [7][8][9].

Table 1: Parameters of Alternating Current Power Supply Sources for Mobile Communication Base Stations

Parameter	Limit deviation
Nominal voltage, *Unom*, V	220/380 (230/400)
Nominal frequency, Hz	50
The set voltage deviation from the nominal value, %, is not more than	10 -15
Voltage transient deviation, %, not more than	□40
The duration of the voltage transient deviation, s, is not more than	3
Transient voltage drop, ms, not more than	10
The set deviation of the frequency from the nominal value, %, is not more than	□5
The distortion coefficient of the sinusoidality of the voltage curve, %, is not more than	10
Voltage unbalance coefficient, %, not more than	5
Voltage pulse: Pulse voltage, V, not more than Pulse duration (at 0.5 amplitude level), µs, not more than	1,8 U_{nom} 1300
Voltage pulse: Pulse voltage, V, not more than Pulse duration, µs, not more than	2000 50

Table 2: Parameters of Uninterruptible Power Supply Sources for Mobile Communication Base Stations

Parametr	Limit deviation
Nominal voltage, *Unom*, V	12, 24 or 48
The set voltage deviation from the nominal value, V, is not greater than:	
12	3 -2
24	+4 -3,6
48	+9 -7,5
The effective value of the harmonic components' power ripples, mV, is not more than:In the frequency range up to 300 Hz From 300 to 150 kHz	50 7
The effective value of the voltage ripples of the sum of the harmonic components in the frequency range from 25 to 150 kHz, mV, is not more than	50
Psophometric value of pulsation, mV, not more than	2
The set voltage deviation at the connection point of the battery, %, is not more than	±1
The voltage transient deviation at a step change of the load from 5 to 100% of the nominal value, %, is not more than	±20
The transition time, s, is not greater than	0,1

By providing the base station with uninterrupted, high-quality electrical power, users can be provided with quality communication. However, currently, several external factors are causing disruptions in the base station's energy supply sources. Outages in local power grids occur due to a number of reasons, including short circuits in low-voltage overhead power lines, which are the main source of power supply to the base station, broken wires between supports on the line, broken insulators on the pole, and voltage drops or surges on the line [10], [11].

The frequency and duration of power outages at mobile communication base stations were analyzed and their impact on the energy system was studied. We conventionally divided the periods of outages at base stations into four classes (Table 3):

- very high frequency interruptions;
- high frequency interruptions;
- medium frequency interruptions;
- low frequency interruptions;

Table 3: Base Station Power Outage Status

Category	Time interval (hours)	Number of power outages	Power outages (%)	Network status	Accumulator cycles
Very high frequency interruptions	0-1	4719	81,069	Stable	4719 cycles
High frequency interruptions	1-2	599	10,29		599 cycles
Medium frequency interruptions	2-6	416	7,147	Partially stable	416 cycles
Low frequency interruptions	6-24	87	1,495	Communication is not available	87 cycles
Total	0-24	5821	100		5821 cycles

The largest share of outages is due to very high-frequency outages, which are short-term, lasting up to 1 hour, accounting for 81.1% of total outages, and the backup energy source during outages is constantly activated by batteries (Figure 1). As a result, the number of charge and discharge cycles of batteries increases, reducing their lifespan. In addition, in the event of a power outage, backup power sources are required to quickly deliver electricity to base station devices.

If there is a delay in the delivery of electricity from backup power sources during outages, the base station system will be completely shut down and restarted. Energy consumption increases significantly due to peak power demand when the system restarts. High-frequency outages (1-2 hours) account for 10.29% of total outages, significantly increasing the charge and discharge cycles of batteries. Although medium-frequency outages were observed relatively less (7.147%), their increased duration reduces the operational life of backup power sources. Although low-frequency outages are the least common (1.495%), their prolonged duration causes batteries to operate at full capacity, resulting in a reduction in charge-discharge cycles.

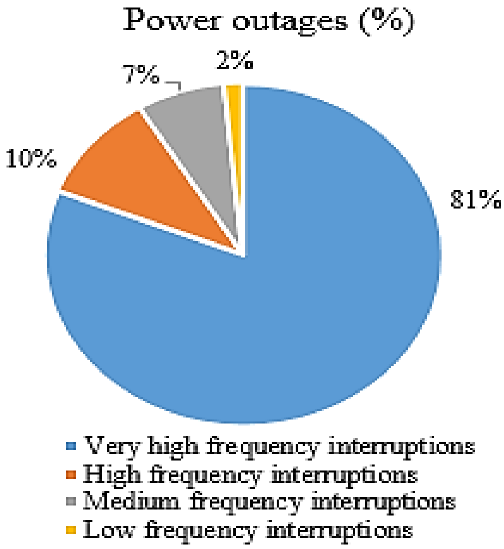

Figure 1: Percentage of Outages in the Base Station Power Supply System

Based on the above, a device has been developed to effectively control electrical power sources, increase system reliability and extend the life of backup power sources. This device is an important basis for providing uninterrupted power to mobile communication base stations [6]. The process of creating the device is shown in Figure 2.

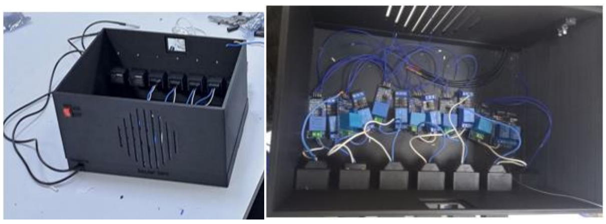

Figure 2: Processes For Creating a Device that Automatically Controls the Power Supply Sources of a Mobile Communication Base Station

This device is designed to automatically control multiple power sources of a mobile communications base station. This device can automatically control energy supply sources such as local power grids, solar panels, wind generators, diesel generators, batteries, and supercapacitors.

The automatic power supply control device works as follows. This device is designed to control and monitor the power supply of mobile communication base stations. It uses local power grids and a diesel generator as power sources, and a set of batteries and supercapacitors for backup power sources [12][13][14][15].

The device monitors the main and backup energy sources in real time using sensors. Based on monitoring data, a centralized control unit controls energy supply sources using communication channels to send control signals. If it detects an interruption in the main power supply, the centralized control unit switches on and controls a series-connected set of supercapacitors, which are effective for short-term interruptions and have a charge/discharge cycle much higher than that of batteries, to supply the main load with electricity using a switch.

During the supply of electricity to the main load, several parameters of the supercapacitors are monitored. When the voltage reaches a certain level, if the interruption in the central power supply sources is not eliminated, the central control unit connects and controls the batteries, which are additional backup energy sources, using a switch to supply electricity to the main load.

In this case, the central control unit also monitors the battery status. When the specified limits are reached, the central control unit starts the diesel generator. The load is provided by the batteries until the diesel generator starts. After the diesel generator is fully started, the load is provided by the generator.

In this way, mobile communication base stations are provided with uninterrupted power supply. In this case, the use of supercapacitors during short-term outages reduces the number of battery charges/discharges and extends the service life, and the load is provided with uninterrupted power supply. [14], [15].

In this case, the monitoring data is stored using a data storage unit. In addition, the data transmission and reception unit transmits the real-time status of energy supply sources to the center using a wireless network.

This allows remote monitoring of the state of energy sources. During charging/discharging of batteries and supercapacitors, their temperature increases, and their overcharging/discharging seriously affects their energy storage capacity. In addition, high humidity can cause corrosion and deterioration of contacts. This reduces the electrical conductivity, damages the internal components of the battery and supercapacitors. Therefore, constant monitoring of the above parameters of the battery and supercapacitors and maintaining them within the specified limits will extend their service life and increase their energy storage capacity. This device was developed taking into account the above when managing electrical energy sources [16][17][18][19].

III. RESULTS

Experimental testing was carried out on the basis of the created physical model. The results of this study made it possible to comprehensively assess the effectiveness of the developed automatic energy management system. During the research, the uninterrupted supply of mobile communication base stations with electricity, the optimal use of available energy sources and the factors affecting them were analyzed. Experimental studies were conducted at a base station located in the Gurlan district of the Khorezm region of the Republic of Uzbekistan from June 1, 2024 to August 12, 2024.

To provide uninterrupted power to the research base station, a 7.5 kWh diesel generator and 2 sets of 4 series-connected 12 V lead-acid batteries with a capacity of 200 A/h are used, and local power grids are used as the primary energy supply source (Figure 3).

Figure 3: Base Station Power Supply Sources in the Study Area

In the pilot tests, a set of supercapacitors was integrated into the existing power supply sources to increase the reliability of the power supply. This power supply system allowed the supercapacitors to act as a quick backup source in the event of power outages.

During the study, the developed device effectively managed the power supply sources based on the control algorithm during a power outage in the main power supply. During the control, supercapacitors provided power to the base station in 88.6% of the total power outages, batteries in 6.8%, and diesel generators in 4.6% of the total power outages until the main power supply was restored (Table 4) (Figure 4). The experiment showed that supercapacitors have high power density and the ability to provide energy quickly in a short time.

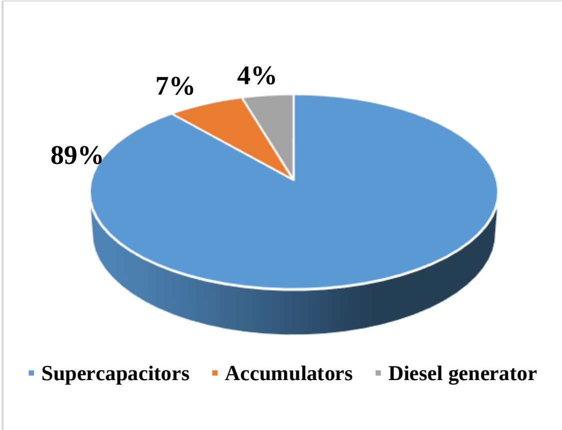

Figure 4: The Share of Power Supply to the Base Station in the Event of an Interruption in the Power Supply System at the Base Station

Table 4: Outages that Occurred During the Study and the Base Station Power Supply Source at the Time of the Outage

The date the outage was observed	**Interruption time**	**Recovered time**	**Outage duration**	**Base station power supply source in case of outage**		
				SC	**AC**	**DG**
01.07.2024	9:14:38	9:30:32	0:15:54	1	0	0
01.07.2024	9:15:44	9:18:09	0:02:25	1	0	0
03.07.2024	15:17:11	18:00:59	2:43:48	1	1	1
03.07.2024	15:16:09	15:20:59	0:04:50	1	0	0
03.07.2024	14:10:31	15:15:14	1:04:43	1	1	0
03.07.2024	14:10:54	14:15:45	0:04:51	1	0	0
03.07.2024	9:36:04	14:08:34	4:32:30	1	1	1
03.07.2024	9:37:47	9:40:12	0:02:25	1	0	0
04.07.2024	11:27:34	12:18:46	0:51:12	1	0	0
04.07.2024	11:28:13	11:30:38	0:02:25	1	0	0
05.07.2024	19:52:14	20:18:53	0:26:39	1	0	0
05.07.2024	19:53:59	19:56:24	0:02:25	1	0	0
05.07.2024	10:24:53	10:50:35	0:25:42	1	0	0
05.07.2024	10:26:01	10:28:26	0:02:25	1	0	0
06.07.2024	0:24:35	0:37:59	0:13:24	1	0	0
06.07.2024	0:24:39	0:27:04	0:02:25	1	0	0
07.07.2024	21:39:41	21:42:06	0:02:25	1	0	0
07.07.2024	21:39:27	21:41:12	0:01:45	1	0	0
07.07.2024	17:32:29	17:55:35	0:23:06	1	0	0
07.07.2024	17:33:11	17:35:36	0:02:25	1	0	0
07.07.2024	16:24:39	16:46:42	0:22:03	1	0	0
07.07.2024	16:25:31	16:27:56	0:02:25	1	0	0
07.07.2024	8:53:34	9:04:43	0:11:09	1	0	0

12.07.2024	10:02:36	10:44:57	0:42:21	1	0	0
12.07.2024	10:03:56	10:06:21	0:02:25	1	0	0
13.07.2024	18:39:57	18:54:15	0:14:18	1	0	0
13.07.2024	18:41:39	18:44:04	0:02:25	1	0	0
13.07.2024	12:05:42	12:34:15	0:28:33	1	0	0
14.07.2024	13:23:38	13:48:29	0:24:51	1	0	0
14.07.2024	13:25:42	13:28:07	0:02:25	1	0	0
14.07.2024	2:44:57	4:59:12	2:14:15	1	1	1
14.07.2024	2:45:06	2:47:31	0:02:25	1	0	0
15.07.2024	16:44:27	17:07:36	0:23:09	1	0	0
15.07.2024	16:45:33	16:47:58	0:02:25	1	0	0
16.07.2024	21:09:34	21:11:59	0:02:25	1	0	0
16.07.2024	21:07:26	21:09:47	0:02:21	1	0	0
16.07.2024	16:06:00	18:59:36	2:53:36	1	1	1
16.07.2024	16:07:28	16:09:53	0:02:25	1	0	0
16.07.2024	14:49:27	15:06:36	0:17:09	1	0	0
16.07.2024	14:50:09	14:52:35	0:02:26	1	0	0
17.07.2024	15:57:47	16:09:44	0:11:57	1	0	0
17.07.2024	15:58:29	16:00:54	0:02:25	1	0	0
17.07.2024	12:15:15	12:28:39	0:13:24	1	0	0
17.07.2024	10:46:33	10:54:18	0:07:45	1	0	0
17.07.2024	10:46:42	10:49:07	0:02:25	1	0	0
18.07.2024	10:49:41	10:52:05	0:02:24	1	0	0
18.07.2024	10:48:59	10:50:47	0:01:48	1	0	0
18.07.2024	10:37:36	10:40:00	0:02:24	1	0	0
18.07.2024	10:37:29	10:38:08	0:00:39	1	0	0
19.07.2024	12:54:35	13:01:53	0:07:18	1	0	0
19.07.2024	12:56:20	12:58:45	0:02:25	1	0	0
20.07.2024	22:49:26	22:50:44	0:01:18	1	0	0
20.07.2024	13:14:00	13:16:25	0:02:25	1	0	0
20.07.2024	13:12:35	13:13:05	0:00:30	1	0	0
21.07.2024	11:33:06	11:35:31	0:02:25	1	0	0
21.07.2024	11:31:11	11:33:44	0:02:33	1	0	0
24.07.2024	19:32:42	19:52:17	0:19:35	1	0	0
24.07.2024	19:33:51	19:36:16	0:02:25	1	0	0
26.07.2024	10:12:17	11:45:59	1:33:42	1	1	0
26.07.2024	10:12:33	10:14:58	0:02:25	1	0	0
30.07.2024	12:21:59	12:31:20	0:09:21	1	0	0
30.07.2024	12:22:14	12:24:39	0:02:25	1	0	0
02.08.2024	14:59:11	15:32:26	0:33:15	1	0	0
02.08.2024	15:00:00	15:02:24	0:02:24	1	0	0
02.08.2024	9:36:15	12:21:23	2:45:08	1	1	0
02.08.2024	9:36:09	9:38:34	0:02:25	1	0	0
06.08.2024	17:06:28	17:08:53	0:02:25	1	0	0
06.08.2024	17:05:50	17:07:23	0:01:33	1	0	0
06.08.2024	12:01:41	13:18:14	1:16:33	1	1	0
06.08.2024	12:01:56	12:04:21	0:02:25	1	0	0

07.08.2024	10:06:26	12:07:41	2:01:15	1	1	0
07.08.2024	10:06:30	10:11:20	0:04:50	1	0	0
08.08.2024	19:07:39	19:30:51	0:23:12	1	0	0
08.08.2024	19:08:35	19:11:00	0:02:25	1	0	0
08.08.2024	14:03:36	14:59:54	0:56:18	1	0	0
08.08.2024	14:04:05	14:06:30	0:02:25	1	0	0
09.08.2024	14:03:27	14:31:54	0:28:27	1	0	0
09.08.2024	14:04:35	14:07:00	0:02:25	1	0	0
09.08.2024	12:34:33	13:39:36	1:05:03	1	1	0
09.08.2024	12:35:11	12:37:36	0:02:25	1	0	0
10.08.2024	14:44:45	15:40:50	0:56:05	1	0	0
10.08.2024	14:46:12	14:48:37	0:02:25	1	0	0
11.08.2024	21:30:30	22:05:45	0:35:15	1	0	0
11.08.2024	21:32:35	21:34:59	0:02:24	1	0	0
12.08.2024	12:06:33	12:09:18	0:02:45	1	0	0
12.08.2024	11:14:26	11:57:57	0:43:31	1	0	0
12.08.2024	11:54:12	11:55:39	0:01:27	1	0	0

Mobile communication base stations consume peak power during the initial startup process. Peak power during a full restart can increase energy consumption by 30–100%. If the entire system restarts at the same time, peak power consumption can increase by 1.5–2 times in a short period of time (a few seconds). The use of the developed device reduced the number of outages. This allowed to increase the overall energy saving indicator by 4-5 percent over time. This indicator was achieved due to the optimal use of various energy sources, intelligent control of energy flows and high-efficiency operation of supercapacitors. In addition, during the operation of the device, it allowed to increase the speed of response to power outages by 10 times. As a result, short-term power outages were eliminated without affecting the operation of mobile communication base stations, and the base station continued to operate continuously (Figure 5).

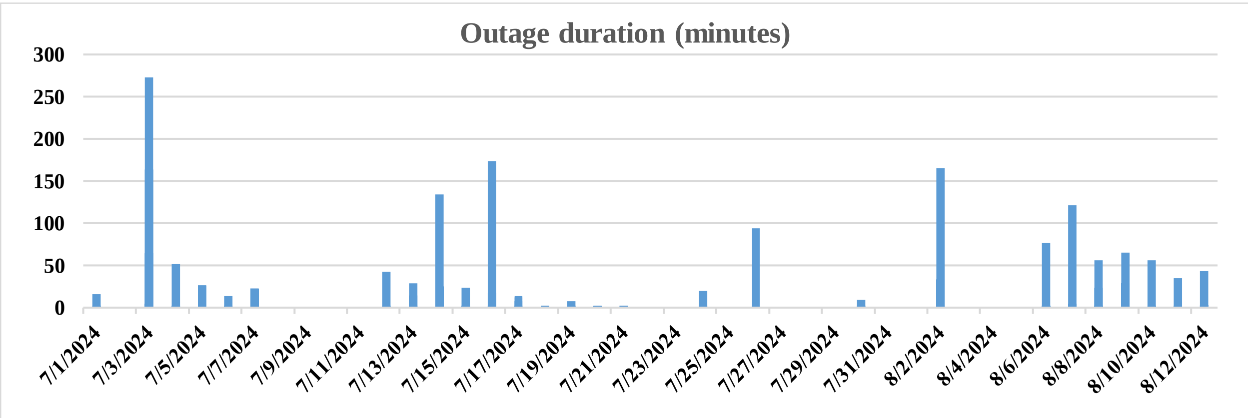

Figure 5: Duration of Outages During the Study Period

When an outage occurs, the device transmits information about the current status of the base station to the assigned employee number via SMS. In addition, the developed device also allows you to determine the current status of the base station by sending a request. Figure 6 shows when an outage occurs and how to determine the current status by sending a request.

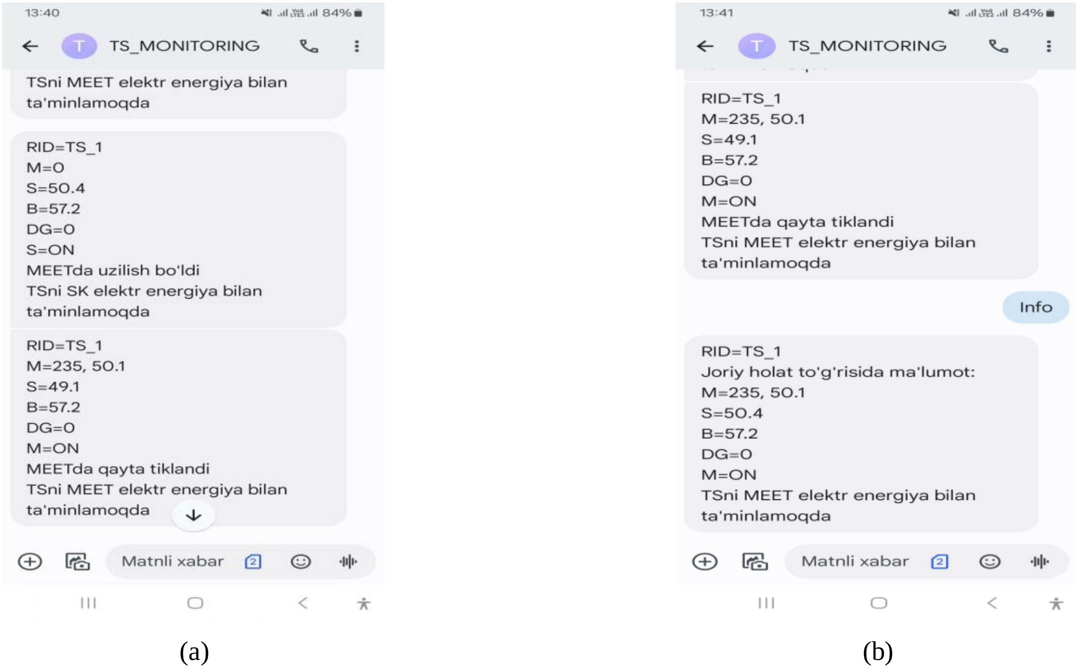

Figure 6: To Receive Information About the Current Situation in the Form of an Sms Message when there is an Outage at the Base Station (a) and by Sending a Request(b)

IV. CONCLUSION

This article evaluates the performance of a mobile communication base station's automatic power supply control device based on experimental test results. As a result of the practical application of the developed device, during the research period, supercapacitors provided the base station with electricity in 88.6% of the total outages, batteries in 6.8%, and diesel generators in 4.6% of the total outages until the main power supply was restored. As a result of the use of supercapacitors during outages lasting up to 1 hour, the battery life cycle increased by 88.6% and the base station was provided with uninterrupted power supply. In addition, the supercapacitors' rapid response to power outages reduced peak power consumption, which allowed for an overall energy efficiency increase of 4-5 percent. The response time to initial outages in the base station's power supply sources was reduced by 10 times. The device provided the mobile communication base station with uninterrupted power, ensuring continuity of operation.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

1. U. K. Matyokubov, M. M. Muradov, and O. B. Djumaniyozov, "Analysis of sustainable energy sources of mobile communication base stations in the case of Khorazm region," in 2022 International Conference on Information Science and Communications Technologies (ICISCT), Tashkent, Uzbekistan, 2022, pp. 1–4, Available from: http://dx.doi.org/10.1109/ICISCT55600.2022.10146885
2. M. o'g'li and M. Muradov, "Enhancing the energy efficiency of wireless sensor networks," Int. Sci. Conf. with Higher Edu. Inst., vol. 1, no. 05.05, 2023. Available from: https://doi.org/10.1016/j.procs.2020.08.028
3. U. O. Qutliyev et al., "Integration of fuzzy set approach for comprehensive study of sustainable functioning of the telecommunication system of Uzbekistan," The Am. J. Eng. Technol., vol. 3, no. 6, pp. 35–46, 2021. Available from: https://doi.org/10.37547/tajet/Volume03Issue06-07
4. U. K. Matyokubov and M. M. Muradov, "Comparison of routing methods in wireless sensor networks," in 2023 IEEE XVI Int. Sci. Tech. Conf. Actual Problems of Electronic Instrument Engineering (APEIE), Novosibirsk, Russia, 2023, pp. 1780–1784, Available from: http://dx.doi.org/10.1109/APEIE59731.2023.10347799
5. O'. Matyokubov and M. Muradov, "Mobil aloqa tayanch stansiyasi elektr ta'minot tizimlaridagi dolzarb muammolar," Int. J. Sci. and Appl. Res., vol. 1, no. 3, pp. 79–83, 2024. Available from: http://dx.doi.org/10.5281/zenodo.14555431
6. M. M. Muradov, "Mobil aloqa tayanch stansiyalarini qayta tiklanuvchan energiya ta'minot manbalaridan foydalangan holda energiya bilan ta'minlash xususiyatlari," Al-Farg'oniy Avlodlari Jurnali, no. 4, vol. 1(8), pp. 245–250, 2024. Available from: http://dx.doi.org/ 10.5281/zenodo.14555431
7. M. M. Muradov, "Elektr energiya ta'minot tizimlari uchun moslashuvchan boshqaruv usulining zarurati," in Rep. Sci. Pract. Conf. on Automation Systems and Green Energy Issues, Qarshi, 2024, pp. 126–128. Available from: https://jurnal.qurilishtalim.uz/dannie/2024_5.pdf
8. O'. K. Matyokubov, M. M. Muradov, and O. B. Djumaniyozov, "Xorazm viloyati misolida mobil aloqa tayanch stansiyalari barqaror energiya manbalarining tahlili," in Int. Sci. Pract. Conf. on Info. Technologies, Networks, and Telecom., Urganch, 2022, pp. 107–111. Available from: https://www.academia.edu/114559922/ERUS
9. U. K. Matyokubov and D. A. Davronbekov, "The impact of mobile communication power supply systems on communication reliability and viability and their solutions," Int. J. Adv. Sci. Technol., vol. 29, no. 5, pp. 3374–3385, 2020. Available from: http://sersc.org/journals/index.php/IJAST/article/view/12023
10. U. K. Matyokubov and D. A. Davronbekov, "Increasing energy efficiency of base stations in mobile communication systems," Acta of Turin Polytechnic University in Tashkent, vol. 10, pp. 1, 2020. Available from: https://shorturl.at/rLtsf
11. D. A. Davronbekov and U. K. Matyokubov, "Influence of communication lines on reliability in mobile communication systems," in 2021 Int. Conf. on Info. Sci. and Commun. Tech.

(ICISCT), IEEE, 2021. Available from: https://doi.org/10.1109/ICISCT52966.2021.9670377

12. D. A. Davronbekov and U. K. Matyokubov, "Algorithms for calculating the structural reliability of a mobile communication system," in 2021 Int. Conf. on Info. Sci. and Commun. Tech. (ICISCT), IEEE, 2021. Available from: https://doi.org/10.1109/ICISCT52966.2021.9670315
13. D. A. Davronbekov and U. K. Matyokubov, "The use of supercapacitors to stabilize the power supply system of the base station of mobile communication," Sci.-Tech. J., vol. 25, no. 1, Art. 1, 2021. Available from: https://shorturl.at/zC6Yu
14. U. K. Matyokubov, M. M. Muradov, and J. F. Yuldoshev, "Development of the method and algorithm of supplying the mobile communication base station with uninterrupted electrical energy," in 2024 IEEE 25th Int. Conf. of Young Professionals in Electron Devices and Materials (EDM), Altai, Russia, 2024, pp. 2400–2406, Available from: https://doi.org/10.1109/EDM61683.2024.10615043
15. M. M. Muradov, "Analysis of power outages at mobile communication base stations," Nauka i Obrazovanie: Teoriya i Praktika, Neftekamsk, Russia, 2024, pp. 17–22. Available from: http://dx.doi.org/10.4018/ijiscram.2014040103
16. H. Khujamatov et al., "ERIRMS evaluation of the reliability of IoT-aided remote monitoring systems of low-voltage overhead transmission lines," Sensors, vol. 24, no. 18, pp. 5970, 2024. Available from: https://doi.org/10.3390/s24185970
17. D. Davronbekov, U. K. Matyokubov, and M. I. Abdullayeva, "Evaluation of reliability indicators of mobile communication system bases," Evaluation, vol. 11, pp. 16–2020, 2020. Available from: https://shorturl.at/oyWYe
18. D. A. Davronbekov, U. K. Matyokubov, and J. A. Aripov, "Analysis of reliability issues in telecommunications networks and power grids," in 4th Int. Sci. Pract. Conf. «Recent Scientific Investigation», 2020. Available from: https://ojs.ukrlogos.in.ua/index.php/interconf/article/view/17166
19. D. A. Abdujalilovich and U. K. Matyokubov, "Reliability of the BTS-BSC system with different types of communication lines between them," Int. J., vol. 9, no. 4, 2020. Available from: http://dx.doi.org/10.30534/ijatcse/2020/362942020