**Brief information about the project**

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| Name of the project | AP09259554 «Development of criteria for assessing the geomagnetically induced currents impact on overhead power lines and oil and gas pipelines» (0121PK00301) |
| Relevance | The relevance of the project objectives is determined by the fact that ground-based technological infrastructures, including power grids, are significantly affected by geomagnetically induced currents, regardless of their location. In countries with vast territories, such as Kazakhstan, long main power transmission lines and pipelines contribute to strengthening the values of induced currents during periods of extreme geoeffective solar events, which affects their regular functioning. |
| Purpose | The goal of the project is to development of criteria for assessing negative electromagnetic effects, considering space factors in conducting ground systems (power lines, pipelines) on the territory of Kazakhstan and creation of a device for recording telluric currents. |
| Objectives | **Tasks of the project:**<br>1. Determine the heliogeophysical conditions leading to the appearance of geomagnetically induced currents at mid-latitudes.<br>2. Develop a map of the distribution of geomagnetically induced currents for the territory of Kazakhstan using models of ionospheric currents and earth conductivity for different levels of geomagnetic activity.<br>3. To develop a device for registering telluric currents with embedded software. |
| Expected and achieved results | Below are brief conclusions for each section separately on the results of the research work in 2021-2023 yy.<br>1) The morphological features of helio-geophysical conditions leading to the appearance of geomagnetically induced currents at mid-latitudes have been determined. Negative electromagnetic effects on main power lines and oil and gas pipelines in Kazakhstan are primarily caused by very large geomagnetic storms (local K-index ≥7) and large magnetic storms (local K-index=6).<br>The geomagnetic situation on the territory of Kazakhstan was studied, considering the accelerated drift of the magnetic pole in the Northern Hemisphere towards the Arctic coast of Russia. According to measurements at the Alma-Ata observatory [43.25° N; 76.92° E] shows that from 1963 to 2023 geomagnetic declination D increased by 30 minutes; on average, geomagnetic declination D increases by 1.9 minutes/year. Values of geomagnetic declination D obtained because of calculations using the IGRF model give good agreement with data obtained from observatory observations, standard deviation 0.04. In practical terms, changes in geomagnetic declinations must be considered during high-precision navigation to reduce errors in determining azimuth. All modern navigation maps contain information about the magnitude of the geomagnetic field declination. These maps need to be constantly updated for the regions of Kazakhstan due to the accelerated movement of the north geomagnetic pole.2<br>2) The effects of geomagnetically induced currents were studied depending on the configuration, length and spatial direction of the power line. The most widespread and longest power transmission lines with an operating voltage of 500 kV on the territory of Kazakhstan, the length of |

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| | which reaches 490 km, are considered. The difference between the values of the simulated values of geomagnetically induced currents calculated for the curved path of power lines and for the straight paths connecting the corresponding substations is shown. For power lines oriented predominantly across the horizontal vector of the geoelectric field, there is a difference of 40% between the values of the voltage induced along the power lines (about 10.4 V) along the curved path of the power lines and along the straight lines connecting the corresponding substations.<br>During geomagnetically disturbed periods, the statistics of emergency outages in Almaty Intersystem Electrical Networks from January 2012 to March 2023 were studied.<br>Criteria have been developed for assessing the impact of geomagnetically induced currents on electric power systems and oil and gas pipelines in Kazakhstan. The measures of protection against negative electromagnetic effects considering space factors in conducting ground systems are proposed and the necessity of their development and application considering the specific conditions and requirements of electric power systems and pipelines in Kazakhstan is established.<br>3) The design documentation for the device for recording telluric currents has been finalized. In terms of improving the design, a design option has been developed for a prototype DCA (dual-channel coupling amplifier) with signal cables connected to connectors in a sealed housing.<br>A prototype of a device for recording telluric currents with built-in software was manufactured, including equipment for receiving, combining and recording linear measurements, containing an analog-to-digital converter; dual-channel coupling amplifier; grounding electrode pins. And the information obtained during testing of a prototype device is saved in the form of files and is suitable for further processing and analysis. A prototype of the device can be used for continuous measurement sessions over a long period of time, in the absence of maintenance personnel. |
| Research team members with their identifiers (Scopus Author ID, Researcher ID, ORCID, if available) and links to relevant profiles | **1) Mukasheva Saule**, scientific project manager, candidate of physical and mathematical sciences, member of the European Geophysical Society EGU (European Geosciences Union).<br>**Scopus Author ID: 6508123068**<br>**Researcher ID: AAP-9855-2020**<br>**ORCID:** http://orcid.org/0000-0002-1609-4430.<br>**2)** Somsikov Vyachaslav, *scientific consultant*, Doctor of Physical and mathematical sciences, professor, member of the American Geophysical Union AGU (American Geophysical Union), a famous scientist in the field of studying dynamic processes in the atmosphere. https://app.webofknowledge.com/author/#/record/1152190.<br>https://www.scopus.com/authid/detail.uri?authorId=6602591126<br>**ResearcherID: T-5158-2017**<br>**https://orcid.org/0000-0003-1005-9367**<br>3) Andreyev Alexey, *executive officer*, PhD doctoral student of KazNU named after Al Farabi, specialty 6D071900 - Radio engineering, electronics and telecommunications.<br>https://app.webofknowledge.com/author/#/record/31471978.<br>**Scopus Author ID: 36994358300** |

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| | Researcher ID in Publons: AAE-4438-2019<br>ORCID: https://orcid.org/0000-0001-7914-5496<br>4) Nurgaliyeva Kuralay, *Researcher*, candidate of physical and mathematical sciences, specialty 25.00.29 - Physics of the atmosphere and hydrosphere, higher education, diploma qualification - physics and chemistry of plasma (KazNU named after al-Farabi).<br>https://app.webofknowledge.com/author/record/10060034<br>**ResearcherID: O-1139-2014**<br>**Scopus Author ID: 6505821072**<br>**ORCID:** https://orcid.org/0000-0002-0696-7277<br>5) Sokolova Olga, *Researcher*, https://app.webofknowledge.com/author/#/record/3412265).'<br>**https://www.scopus.com/authid/detail.uri?authorId=57200591026**<br>**Scopus Author ID: 57200591026**<br>**ORCID:** http://orcid.org/0000-0003-1349-1235<br>6) Kapytin Vitaliy, *Researcher*,<br>https://www.scopus.com/authid/detail.uri?authorId=57201291120<br>**Scopus Author ID: 57201291120**<br>**ORCID:** https://orcid.org/0000-0002-2001-9847 |
| List of publications with links to them | **20 works have been published.**<br>**- Articles published in peer-reviewed foreign scientific publications indexed by the Web of Science and Scopus databases (6 papers):**<br>1 Andreyev A.B., Kapytin V.I., Mukasheva S.N. Development of a system for detecting traveling ionospheric disturbances based on GNSS data // Proc. 27th Intern. Symp. of SPIE. -2021. -Vol. 11916. -P. 119168J-1 – 119168-4. doi: 10.1117/12.2600692. Percentile in Scopus – 20% Electrical and Electronic Engineering. SjR 0.18.<br>2 Somsikov V. M., Abylay A. M., Kuvatova D. B. Physics of evolution and unity of physics // Journal of Physics: Conference Series. - 2021. - Vol. 2094. Applied physics. 022029. doi: 10.1088/1742-6596/2094/2/022029. Percentile in Scopus – 22% General Physics and Astronomy, SjR = 0.21.<br>3 Andreyev A., Kapytin V., Mukasheva S., Somsikov V. Development of a System for Detecting Traveling Ionospheric Disturbances Based on GNSS Data // Atmosphere. -2022. -Vol. 13. -P. 183-189. https://doi.org/10.3390/atmos13020183. Q2. SjR 0.69. Percentile in Scopus – 71% Environmental Science (miscellaneous).<br>4 Vassilyev I.V., Andreyev A.B., Kapytin V.I., Mukasheva S.N. Experience in Registering Higher Harmonics of Industrial Frequency Currents on a Stand for Measuring Telluric Currents // Russian Electrical Engineering. - 2023. - Vol. 94, No. 4. - P. 240-244. doi: 10.3103/S1068371223040107. SjR 0.411. Q2. Percentile in Scopus – 61% Electrical and Electronic Engineering.<br>5 Somsikov V.M. Physics of evolution and structure of matter // AIP Conference Proceedings 2731, 2023. - P. 020004. doi: https://doi.org/10.1063/5.0133080. SjR 0.16. Percentile in Scopus – 19% General Physics and Astronomy.<br>6 Andreyev, A. B., Mukasheva, S. N., Kapytin, V. I., & Sokolova, O. I. (2023). Estimating geomagnetically induced currents in high-voltage power lines for the territory of Kazakhstan. Space Weather, 21, e2023SW003639. https://doi.org/10.1029/2023SW003639. |

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| | https://doi.org/10.3390/atmos13020183. Q2. SjR 1.08 Percentile in Scopus – 73% Atmospheric Science<br>**- Articles published in publications indexed by the Russian Science Citation Index – 4 articles:**<br>7 Somsikov V. M., Chunchuzov I. P., Dzhahanshir A., Mukasheva S. N. Solnechnyiy terminator i ionosfernoe rasprostranenie radiovoln // Tehnika radiosvyazi. -2021. Vyip. 4 (51).- S. 15-23. doi 10.33286/2075-8693-2021-51-15-23. RSCI – 0,17. (in Russian)<br>8 Somsikov V.M. Rol simmetrii v fizike evolyutsii // Sovremennyie tehnika i tehnologii v nauchnyih issledovaniyah: sb. mater. XIV mezhdunar. konf. molodyih uchenyih i studentov. - Bishkek: Nauchnaya stantsiya RAN, 2022. - S. 421-429. (in Russian)<br>9 Vasilev I. V., Andreev A. B., Kapyitin V. I., Mukasheva S. N. Opyit registratsii vyisshih garmonik tokov promyishlennoy chastotyi na stende dlya izmereniya telluricheskih tokov // Elektrotehnika. - 2023. - # 4. - S. 20-24. – doi 10.53891/00135860_2023_4_20. RSCI – 0,594. (in Russian)<br>10. Turdyibaeva Zh. A., Mukasheva S.N. Ionosfernyie effektyi solnechnyih vspyishek nad Kazahstanskim regionom po osnove globalnyih kart polnogo elektronnogo soderzhaniya // Sovremennyie tehnika i tehnologii v nauchnyih issledovaniyah: programma XV mezhdunar. konf. molodyih uchenyih i studentov. - Bishkek: Nauchnaya stantsiya RAN, 2023.– P. 183-187. (in Russian).<br>Турдыбаева Ж. А., Мукашева С.Н. Ионосферные эффекты<br>**- Articles published in publications recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, indexed by the Kazakhstan Citation Database – 4 articles:**<br>11 Mukasheva S.N., Sokolova O.I. Ionosfernyie buri nad Kazahstanom po dannyim ob integralnom elektronnom soderzhanii // Vestnik. Seriya fizicheskaya. -2022. - #1 (80). - S.88-96. https://doi.org/10.26577/RCPh.2022.v80.i1.10. KazCD – 0,071. (in Russian)<br>12 Mukasheva S. N., Sokolova O. I. Geomagnitnoe sklonenie i ego prostranstvenno-vremennyie izmeneniya po dannyim dvuh sredneshirotnyih observatoriy // Dokladyi NAN RK. - 2022. - # 4. - S.126-135. doi:10.32014/2022.2518-1483.176. KazCD – 0,32. (in Russian)<br>13 Andreev A. B., Kapyitin V. I., Sokolova O. I. Morfologicheskie osobennosti gelio-geofizicheskih usloviy, privodyaschih k poyavleniyu geomagnitno indutsirovannyih tokov na territorii Kazahstana // Zhurnal Problem evolyutsiy otkryityih sistem. -2022. - T. 21, # 1-2. - S. 65-72. https://doi.org/10.26577/JPEOS.2022.v24.i1.i3. KazCD – 0,16. (in Russian)<br>14 Nurğalïeva Q.E. Ğarış rayınıñ orta endikte geomagnïtti ïndwkcïyalanğan toktıñ payda bolwına äser etwin zerttew // Vestnïk. Serïya fïzïçeskaya. -2023. -№1 (84). - S. 48-55. https://doi.org/10.26577/RCPh.2023.v84.i1.06. KazCD – 0,071 (in Kazakh)<br>**- Published in the proceedings of international conferences (6 papers):** |

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| | 15 Andreev A.B., Kapyitin V.I., Mukasheva S.N. Razrabotka sistemyi detektirovaniya peremeschayuschihsya ionosfernyih vozmuscheniy na osnove dannyih GNSS // Optika atmosferyi i okeana. Fizika atmosferyi: sb. dokl. mezhdunar. simp. - M.: Atmosphere and Ocean Optics. Atmospheric Physics. https://symp.iao.ru/files/symp/aoo/27/ru/abstr_13725.pdf. (in Russian)<br>16 Somsikov V.M. D-Entropy in Classical Mechanics // CHAOS. Springer Proceedings in Complexity. - Springer, Cham., 2022. - P. 481-493. https://doi.org/10.1007/978-3-030-96964-6_33.<br>17 Mukasheva S., Andreyev A., Kapytin V., Sokolova O. Geomagnetically Induced Currents over Kazakhstan during Large Geomagnetic Storms / Proc. EGU General Assembly, 2022. EGU22-3338. https://doi.org/10.5194/egusphere-egu22-3338.<br>18 Nurgaliyeva K. Analysis of correlations between geomagnetic storms and emergency shutdowns in the part of Almaty power grid for 2016-2021// Proc. EGU General Assembly, 2022. EGU22-3317 https://doi.org/10.5194/egusphere-egu22-3317.<br>19 Somsikov V.M. "Order" and "Chaos" / in the Evolution of Matter. Book: Springer Proceedings in Complexity Series, 2023. doi: 10.1007/978-3-031-27082-6.<br>20 Nurgaliyeva K., Mukasheva S., Andreyev A., Sokolova O., Ussenova N., Zhunisbekov D. Estimation of Geomagnetically Induced Currents Affect on Power Grid Based on Measurements of Mid-Latitude Geomagnetic Observatories // Proc. 18-th International Conference on Electrical Machines, Drives and Power Systems (ELMA). IEEE Catalog Number: CFP23L07-USB, 2023. - P. 294-297. |
| Patents | - A patent for the invention has been obtained:<br>1 Patent 36189 Republic of Kazakhstan, IPC G01R 19/00. Instrument for the registration of telluric currents and the method for measuring telluric currents/ I. V. Vassilyev, S.N. Mukasheva, A.B. Andreyev, V.M. Somsikov, V.J. Kapytin, O.I. Sokolova; applicant and patent holder «Granit» Special Design and Technology Bureau» Limited Liability Partnership (KZ). - № 2022/0139.1; decl. 04.03.2022; publ. 2023-04-21. Industrial property. Bulletin. -2023. № 16. - P. 6. |

**Applications**

1) Patent

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ РЕСПУБЛИКА КАЗАХСТАН

REPUBLIC OF KAZAKHSTAN

ПАТЕНТ
PATENT

№ 36189

ӨНЕРТАБЫСҚА / НА ИЗОБРЕТЕНИЕ / FOR INVENTION

(21) 2022/0139.1

(22) 04.03.2022

(45) 21.04.2023

(54) Теллуриялық токтарды тіркеуге арналған құрылғы және теллуриялық токтарды өлшеу тәсілі
Прибор для регистрации теллурических токов и способ измерения теллурических токов
Instrument for the registration of telluric currents and the method for measuring telluric currents

(73) «Гранит» арнаулы конструкторлық-технологиялық бюросы» жауапкершілігі шектеулі серіктестігі (KZ)
Товарищество с ограниченной ответственностью «Специальное конструкторско-технологическое бюро «Гранит» (KZ)
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ЭЦҚ қол қойылды
Подписано ЭЦП
Signed with EDS

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«Ұлттық интеллектік меншік институты» РМК директоры
Директор РГП «Национальный институт интеллектуальной собственности»
Director of RSE «National institute of intellectual property»

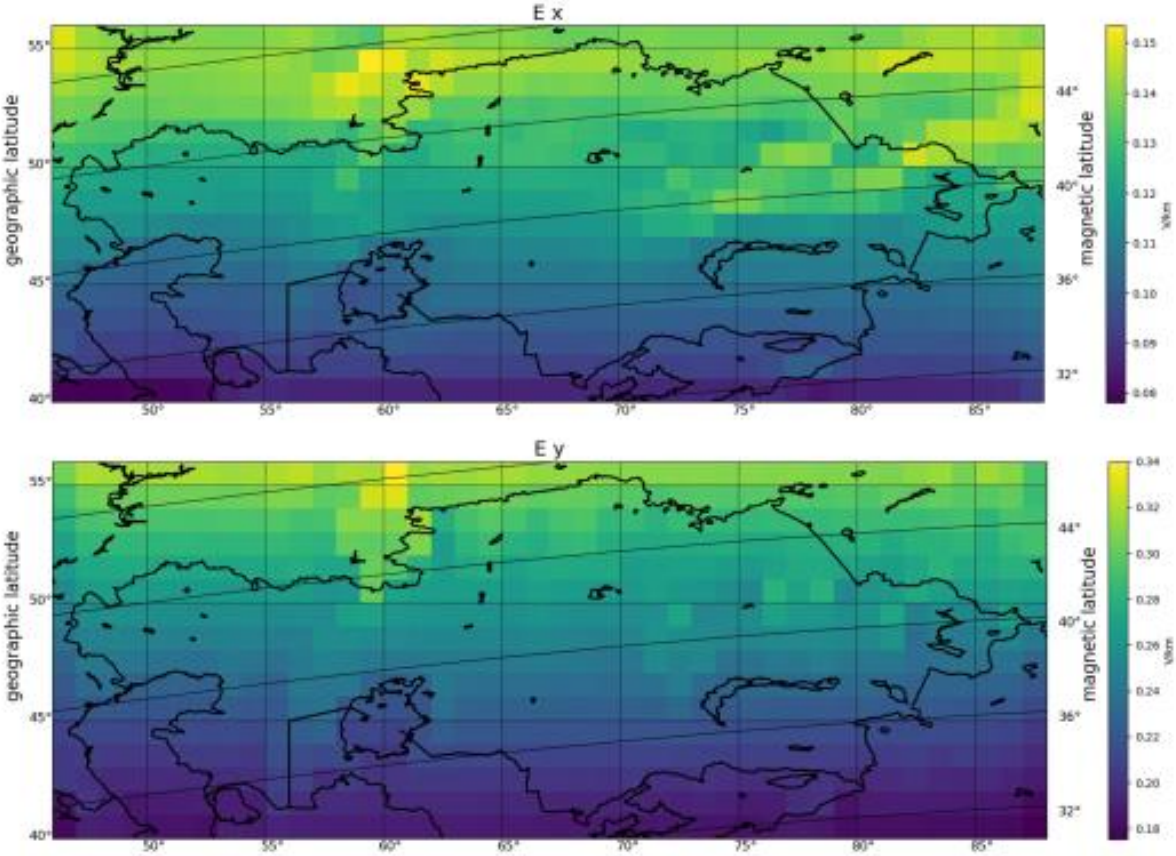


Figure 2 – The maximum values of the geoelectric field in the direction of north-south (Ex) and west-east (Ey).

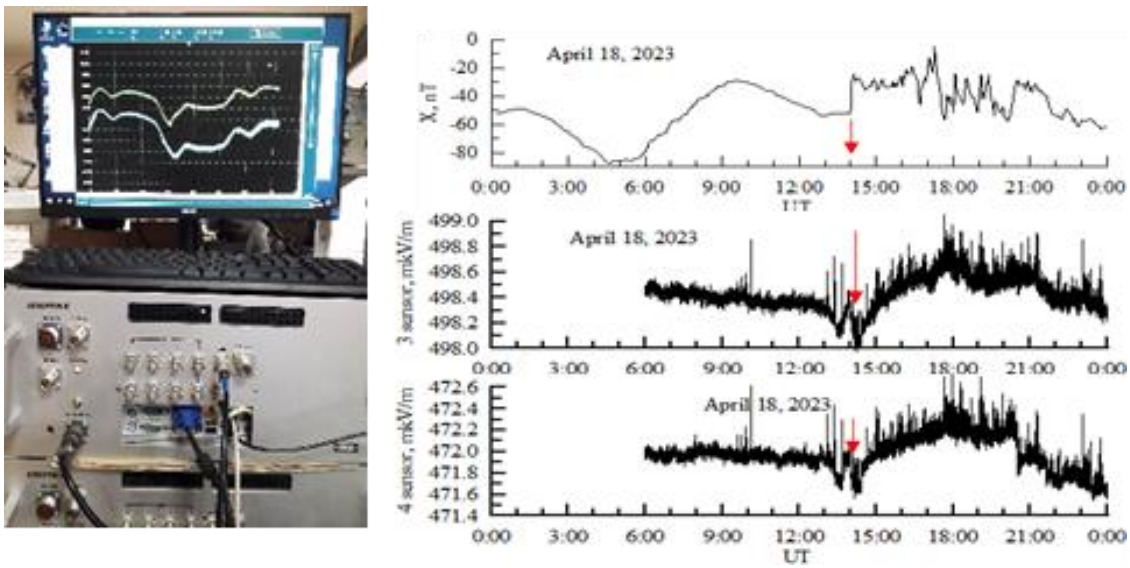


Figure 3 – Photo of a prototype device for recording teturic currents and measuring