

**18-th INTERNATIONAL CONFERENCE
ON ELECTRICAL MACHINES,
DRIVES AND POWER SYSTEMS**



ELMA 2023

PROCEEDINGS

**June 29 - July 1 2023
Varna, Bulgaria**

**2023 18-th Conference on Electrical Machines,
Drives and Power Systems (ELMA)**



ELMA 2023

Proceedings

**June 29 - July 1 2023,
VARNA, BULGARIA**

ISBN 979-8-3503-2810-3

IEEE Catalog Number: CFP23L07-USB

Organised by:

**Union of Electronics, Electrical Engineering and Telecommunications
(CEEC)**

IEEE Bulgaria Section

With the support of:

Technical University of Varna

Technical University of Sofia

Technical University of Gabrovo

University of Ruse

Federation of the Scientific Engineering Unions (FNTS)

2023 18-th Conference on Electrical Machines, Drives and Power Systems (ELMA)

Copyright and Reprint Permission:

Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limit of U.S. copyright law for private use of patrons those articles in this volume that carry a code at the bottom of the first page, provided the per-copy fee indicated in the code is paid through Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923.

For reprint or republication permission, email to IEEE Copyrights Manager at pubs-permissions@ieee.org.

All rights reserved. Copyright ©2023 by IEEE.

ISBN 979-8-3503-2810-3

IEEE Catalog Number: CFP23L07-USB

Disclaimer: The authors are fully responsible for respecting the authors' rights, industrial and patent properties.

For all technical inquiries about this Proceedings contact:

Bohos Aprahamian, e-mail: bohos@tu-varna.bg, phone: +359 52 383 578

TABLE OF CONTENTS

1.	HYBRID ENERGY STORAGE SYSTEM TO INCREASE ENERGY EFFICIENCY DURING REGENERATIVE BRAKING OF URBAN ELECTRICAL TRANSPORT	1
	<i>Valentin Totev, Hristo Vasilev, Vultchan Gueorgiev and Ivan Angelov</i>	
2.	BIDIRECTIONAL FLYING INDUCTOR CONVERTER BASED ON KARSCHNY TOPOLOGY	5
	<i>Yovko Rakanov and Andrey Mirev</i>	
3.	FEASIBILITY STUDY OF A HYBRID EXCITED CLAW-POLE ALTERNATOR.....	9
	<i>Ivan Bachev, Vladimir Lazarov, Ludmil Stoyanov and Zahari Zarkov</i>	
4.	APPLICATION OF PID ALGORITHMS TO CONTROL ROBOTIC PLATFORM USING SIMULINK	13
	<i>Martin Dejanov</i>	
5.	MODELLING OF A DC GENERATOR IN MATLAB ENVIRONMENT DURING ONLINE LEARNING.....	17
	<i>Vyara Ruseva, Anka Krasteva and Konstantin Koev</i>	
6.	IMPACT OF DECARBONISATION IN THE ENERGY SECTOR ON LOW-VOLTAGE DISTRIBUTION NETWORKS	21
	<i>Ivan Tonev and Nikolay Nikolaev</i>	
7.	BACKSTEPPING CONTROL OF A PHASE SHIFTED FULL BRIDGE DC/DC CONVERTER FOR EV FAST CHARGERS	27
	<i>Achraf Saadaoui, Mohammed Ouassaid and Mohamed Maaroufi</i>	
8.	OPERATIONAL TORQUE CHARACTERISTICS OF INNOVATIVE COAXIAL MAGNETIC GEAR'S CONSTRUCTIONS	33
	<i>Miglenna Todorova and Iliana Marinova</i>	
9.	INVERTER MODEL OPTIMIZATION IN SIMULINK SOFTWARE ENVIRONMENT.....	39
	<i>Mladen Proykov, Neli Simeonova and Vasil Ivanov</i>	
10.	CLASSIFICATION OF FACTORS AFFECTING EMPLOYEE SATISFACTION IN MODERN BUSINESS ORGANIZATIONS	43
	<i>Boris Gramchev, Svetlana Lesidrenska and Svetlana Dimitrakieva</i>	
11.	IMPLEMENTATION OF PLC-BASED COOLING SYSTEM CONTROL OF AN INDUSTRIAL HALL WHERE A LARGE AMOUNT OF HEAT IS EMITTED	46
	<i>Bohos Aprahamian and Veselin Vasilev</i>	
12.	DESIGN FOR SUSTAINABLE BEHAVIOR: A FOCUS ON SUSTAINABLE ENERGY	49
	<i>Ivaylo Tsanov</i>	
13.	ANALYTICAL AND SIMULATION STUDY OF THE POWER LOSSES OF A SWITCHED RELUCTANCE MOTOR.....	53
	<i>Dimitar Yankov, Tsvetana Grigorova and Ivan Maradzhiev</i>	
14.	STUDY OF CONVERTERS FOR ENERGY STORAGE SYSTEMS IN PARALLEL OPERATION OF MODULES OR ELEMENTS.....	57
	<i>Dimitar Arnaudov, Teodora Todorova and Vladimir Dimitrov</i>	
15.	IDENTIFYING DIFFERENCES BETWEEN POWER SYSTEM OF CONVENTIONAL AND AUTONOMOUS SHIP WITH RESPECT TO THEIR SAFETY ASSESSMENT.....	61
	<i>Ivana Jovanović, Maja Perčić and Nikola Vladimir</i>	

16. CALCULATION OF TEMPERATURE DISTRIBUTION AT CABLE JOINTS USING HYBRID BOUNDARY ELEMENTS METHOD	66
<i>Dusan Jevtic, Nebojsa Raicevic, Ana Vuckovic, Mirjana Peric and Slavoljub Aleksic</i>	
17. DESIGN OF AN ELECTRONIC SYSTEM FOR REGENERATION OF POTENTIAL-INDUCED DEGRADATION (PID) IN PV INSTALLATIONS.....	70
<i>Atanas Kabakchiev, Boris Evstatiev and Dimitar Trifonov</i>	
18. ENERGY RESOURCES AS A FACTOR FOR STABILITY IN EUROPE IN THE 20TH CENTURY	75
<i>Mariya Zheleva</i>	
19. A MTTFD ESTIMATION APPROACH FOR ELECTRONIC MODULES PART OF SAFETY-RELATED CONTROL SYSTEMS.....	79
<i>Toncho Papanchev, Svetlozar Zahariev and Angel Marinov</i>	
20. COMPUTER-BASED METHODS FOR STUDENT TRAINING IN THE FIELD OF ELECTRICITY SUPPLY.....	83
<i>Vyara Ruseva, Anka Krasteva and Konstantin Koev</i>	
21. STRUCTURES AND TOPOLOGIES FOR REALIZATION OF CHARGING STATION FOR EVS.....	87
<i>Andrei Borisov, Gergana Vacheva and Nikolay Hinov</i>	
22. DETERMINATION OF THE LEVEL OF VIBROACTIVITY OF THE TRACTION MOTOR-GEAR UNITS.....	91
<i>Genadijs Kobenkins, Marks Marinbahs, Anatolijs Bizans, Nikita Rilevs and Olegs Sliskis</i>	
23. COMPARATIVE ANALYSIS OF OZONE GENERATING DEVICES	95
<i>Tatyana Dimova, Bohos Aprahamian and Mariya Marinova</i>	
24. ATTENTION DETECTION IN VIRTUAL EDUCATIONAL LABORATORY.....	99
<i>Evgeniy Mendeleev, Daria Burtseva, Roman Petrov, Olga Alekseyeva, Slavcho Bozhkov, Ivan Milenov and Penko Bozhkov</i>	
25. SIMULATION MODEL FOR EVALUATION OF POWER QUALITY INDICATORS IN INDUSTRIAL POWER SUPPLY SYSTEMS WITH GRID-TIED PV SYSTEM.....	102
<i>Yavor Lozanov, Svetlana Tzvetkova and Angel Petleshkov</i>	
26. SOCIAL WELLBEING AND ENERGY POVERTY	106
<i>Krasimira Georgieva</i>	
27. RESEARCH OF ASYMMETRIC MAGNETOELECTRIC STRUCTURES ON SUBSTRATES	110
<i>Evgeniy Kuzmin, Roman Petrov, Viktor Kiselev, Vasily Misilin, Slavcho Bozhkov, Ivan Milenov and Penko Bozhkov</i>	
28. DESIGN OF DIGITAL PHASE FILTERS USING MATLAB.....	113
<i>Adriana Borodzhieva and Snezhinka Zaharieva</i>	
29. ALGORITHM FOR GENERATING HUMAN EYE IRIS TEXTURE CODE	117
<i>Gergana Spasova</i>	
30. MAIN CHARACTERISTICS IN MEASURING TEAM COMMUNICATION AS A MEANS OF IMPROVING TEAM PERFORMANCE.....	121
<i>Boris Gramchev, Svetlana Dimitrakieva and Svetlana Lesidrenska</i>	
31. THEORETICAL MODEL FOR EVALUATION OF THE ENERGY EFFICIENCY OF A HOME BREAD MAKER	124
<i>Yanita Slavova and Mariya Marinova</i>	
32. LOW-COST REMOTE LAB ON RENEWABLE ENERGY SOURCES WITH A FOCUS ON STEM EDUCATION.....	128
<i>Todor Yordanov, Nicolay Mihailov and Katerina Gabrovksa-Evstatieva</i>	
33. PROBLEMS WITH MEASUREMENT AT THE BORDERS BETWEEN ELECTRICITY TRANSMISSION AND DISTRIBUTION NETWORKS IN BULGARIA	133
<i>Velichko Atanasov and Dimo Stoilov</i>	

34. FAULTS ANALYSIS OF THE ELECTRICAL EQUIPMENT IN A COMPANY FROM THE MINING INDUSTRY	137
<i>Svetlana Tzvetkova, Yavor Lozanov and Angel Petleshkov</i>	
35. BRAKING MODES ENERGY UTILIZATION IN DC PUBLIC TRANSPORTATION	141
<i>Vultchan Gueorgiev</i>	
36. ROLE OF THE LEADER IN THE ANTI-CRISIS MANAGEMENT OF ENERGY SECTOR INDUSTRY	145
<i>Marina Marinova-Stoyanova</i>	
37. STUDY ON POWER CONSUMPTION MODES AND POWER QUALITY ACCORDING TO IEEE 1459 STANDARD IN THE ELECTRIC POWER SUPPLY SYSTEMS OF PUBLIC BUILDINGS	149
<i>Valentin Gyurov and Milen Duganov</i>	
38. APPLICATION OF CONVOLUTIONAL NEURAL NETWORKS AND SIGNAL PROCESSING TECHNIQUES TO IDENTIFY AND FILTER NOISE FROM ECG SIGNALS	154
<i>Veselin Atanasov</i>	
39. COMPARISON OF HYBRID MODELS FOR PV POWER OUTPUT FORECASTING – APPLICATION TO ORYAHOVO, BULGARIA	159
<i>Ludmil Stoyanov and Iva Draganovska</i>	
40. EDUCATIONAL POWER LOGGER FOR ELECTRICAL MACHINES LABORATORY EXPERIMENTS	163
<i>Kerem Kontas, Diëgo Zuidervliet and Peter van Duijsen</i>	
41. EXPERIMENTAL STUDY OF THE TEMPERATURE FIELD OF AN ELECTRONIC MODULE	167
<i>Boris Evstatiev and Nadezhda Evstatieva</i>	
42. POWER-TO-HEAT IN DISTRICT HEATING SYSTEMS – A CASE STUDY FOR SOFIA'S DHC	171
<i>Viktor Garbev</i>	
43. APPLYING A RECURRENT NEURAL NETWORK TO THE BEHAVIOUR OF AN AUTONOMOUS AGENT	175
<i>Vanya Markova and Ventseslav Shopov</i>	
44. ALGORITHM FOR IRIS SEGMENTATION IN HUMAN EYE.....	179
<i>Gergana Spasova</i>	
45. COMPARATIVE EVALUATION OF COMMUNICATION PROTOCOLS IN THE AUTOMOTIVE INDUSTRY	183
<i>Marieta Yordanova and Aydan Haka</i>	
46. CONTROL ALGORITHM DEVELOPMENT OF ELECTRICAL DRIVES BY USING FINITE ELEMENT MODEL IN CONNECTED MATLAB/SIMULINK AND JMAG FRAMEWORK.....	187
<i>György Istenes and Krisztián Horváth</i>	
47. WEB-BASED INFORMATION PORTAL FOR BUSINESS PARTNERS - BASIS FOR PROFESSIONAL GUIDANCE FOR GRADUATES	191
<i>Ivan Evstatiev and Georgi Georgiev</i>	
48. CHARGING STATION INFRASTRUCTURE AND STANDARDS FOR ELECTRIC VEHICLES - STATE, PROBLEMS AND FUTURE TRENDS	195
<i>Andrei Borisov, Gergana Vacheva and Nikolay Hinov</i>	
49. STUDY OF THE LONGITUDINAL DYNAMIC PARAMETERS OF TWO-WHEELED ELECTRIC VEHICLES	199
<i>Daniel Lyubenov, Georgi Kadikyanov, Seher Kadirova and Zhivko Kolev</i>	

50.	EXPERIMENTAL STUDY OF INSULATION COMPOSITE MATERIALS ELECTRICAL PROPERTIES IN LIQUID NITROGEN	203
	<i>Georgi Ivanov, Valentin Mateev and Iliana Marinova</i>	
51.	SYSTEM FOR STRING MONITORING IN SMALL EXPERIMENTAL PV PLANTS	207
	<i>Nikolay Valov, Boris Evstatiev, Tsvetelina Mladenova, Vladislav Hinkov and Nicolay Mihailov</i>	
52.	SIMULATION ENVIRONMENT FOR EXAMINING THE PAIRING METHODS IN BLE TECHNOLOGY	212
	<i>Aydan Haka, Yordan Yordanov, Diyan Dinev, Veneta Aleksieva and Hristo Valchanov</i>	
53.	A MODEL BASED COMPARISON ON THE EFFICIENCY OF ELECTRIC VEHICLES TO CONVENTIONAL VEHICLES	216
	<i>Valentin Totev</i>	
54.	APPLYING A PROBLEM-BASED LEARNING IN THE TOPIC OF MODELLING OF THE POWER AND IMPROVEMENT THE VOLTAGE STABILITY OF WIND TURBINES	221
	<i>Ivaylo Stoyanov, Vasil Ivanov and Selahattin Kosunalp</i>	
55.	ANALYSIS OF LORA RSSI DATA USING SIMULATIONS AND REAL DEVICES	225
	<i>Diyan Dinev, Aydin Haka, Veneta Aleksieva and Hristo Valchanov</i>	
56.	A REMOTE LAB FOR EXPERIMENTAL STUDY OF DC MOTORS	229
	<i>Teodor Nenov, Boris Evstatiev and Seher Kadirova</i>	
57.	COMPARATIVE ANALYSIS OF THE CHANGE OF TOUCH AND STEP VOLTAGES AT THE FLOW OF LIGHTNING CURRENTS IN EARTHING GRIDS WITH DIFFERENT MESH SIZES	233
	<i>Rositsa Dimitrova and Milena Ivanova</i>	
58.	ANALYSIS OF STUDENTS SATISFACTION WITH DISTANCE LEARNING AND THE ADVANTAGES AND DISADVANTAGES OF LABORATORY WORKS WITH COMPUTER SIMULATION OF ELECTRONIC ANALOG CIRCUITS.....	237
	<i>Kuralay Nurgaliyeva, Kamila Mirkhamitova, Asylgul Gabdullina and Assel Igenbayeva</i>	
59.	BIBLIOMETRIC ANALYSIS OF TECHNOLOGICAL AND EFFICIENCY DEVELOPMENT IN PHOTOVOLTAIC SYSTEMS.....	241
	<i>Svilen Simeonov, Angel Marinov and Svetlozar Zahariev</i>	
60.	OXYHYDROGEN – AN OVERVIEW OF THE TECHNOLOGY, APPLICATION AND PRODUCTION FACTORS	244
	<i>Kalin Nikolov</i>	
61.	FACTORS INFLUENCING THE PUBLIC SENTIMENT ON NUCLEAR ENERGY INVESTMENT IN EUROPEAN UNION MEMBER STATES	250
	<i>Dafina Nikolova and Dimo Stoilov</i>	
62.	CONSIDERATIONS ON ELECTROMAGNETIC DISTURBANCES APPEARING IN ELECTRICAL ENERGY SMART METERING SYSTEMS	259
	<i>Silvia-Maria Diga, Nicolae Diga, Paul-Mihai Mircea, Ion Patru, Marian-Ştefan Nicolae and Ion Mircea</i>	
63.	ENERGY-EFFICIENT DC MOTOR SPEED CONTROL USING THE GENETIC ALGORITHM	263
	<i>Donka Ivanova and Nikolay Valov</i>	
64.	MODELING THE ENERGY STORAGE SYSTEM FOR DIFFERENT FORMS OF DISCHARGE CURRENT	269
	<i>Hristiyan Kanchev, Krasimir Kishkin and Dimitar Arnaudov</i>	
65.	DESIGN OF MULTIPLE-OUTPUT FLYBACK CONVERTER WITH INDEPENDENTLY CONTROLLED OUTPUTS FOR TV POWER SUPPLY	273
	<i>Ramazan Düzgün, Mehmet Parlak and İsmail Yilmazlar</i>	

66. COMPARISON OF EXTENDED AND UNSCENTED KALMAN FILTERS WITH AND WITHOUT USING MECHANICAL MODEL FOR SPEED SENSORLESS CONTROL OF INDUCTION MACHINES	277
<i>Krisztián Horváth</i>	
67. DIFFERENCE BETWEEN MEASURED AND REAL VALUE IN ILLUMINANCE ESTIMATION	281
<i>Iva Petrinska and Dilyan Ivanov</i>	
68. PARAMETRIC 3D FEM ANALYSIS OF AN IRON-CORED COIL THERMAL PROPERTIES	285
<i>Ilona Iatcheva and Denitsa Darzhanova</i>	
69. DESIGN OF AN ELECTRONIC SYSTEM FOR CONTROL OF PV-POWERED IRRIGATION PROCESSES	289
<i>Reni Kabakchieva, Boris Evstatiev and Katerina Gabrovska-Evstatieva</i>	
70. ESTIMATION OF GEOMAGNETICALLY INDUCED CURRENTS AFFECT ON POWER GRID BASED ON MEASUREMENTS OF MID-LATITUDE GEOMAGNETIC OBSERVATORIES	294
<i>Kuralay Nurgaliyeva, Saule Mukasheva, Alexey Andreyev, Olga Sokolova, Nazugum Ussenova and Doszhan Zhunisbekov</i>	
71. APPLICATION OF HYBRID INVERTERS IN PHOTOVOLTAIC SYSTEMS.....	298
<i>Valentin Milenov and Zahari Zarkov</i>	
72. APPLICATION OF IOT IN UPGRADING AUTOMATIC CONTROL OF ROPE-POLY-STRAP LIFTING SYSTEMS FOR CRANES AND ROTARY EXCAVATORS	303
<i>Stanislav Georgiev, Petko Nedyalkov and Teodora Hristova</i>	
73. THE PSYCHOLOGY OF SUSTAINABLE ENERGY	307
<i>Ivaylo Tsanov</i>	
74. APPLICATION OF VIBRODIAGNOSTICS FOR DIAGNOSIS AND ANALYSIS OF DEFECTS CAUSED BY THE FLOW OF BEARING CURRENTS IN ELECTRICAL DRIVES	311
<i>Dragomir Dragnev and Bohos Aprahamian</i>	
75. 3D PRINTED DESIGNS FOR PERMANENT MAGNETS FIXATION ON HIGH SPEED ROTORS	315
<i>Martin Ralchev, Valentin Mateev and Iliana Marinova</i>	
76. THE DEVELOPMENT OF AN UNIVERSAL SIX LEG INVERTER FOR ELECTRICAL DRIVES LABORATORY EXPERIMENTS.....	319
<i>Axel Drop, Diëgo Zuidervliet and Peter van Duijsen</i>	
77. ANALYSIS OF THE PHOTOBIOLOGICAL IMPACT OF LED LIGHT SOURCES IN THE CONTEXT OF STANDARDIZATION REQUIREMENTS FOR REDUCTION OF BLUE LIGHT EMISSION.....	323
<i>Valentin Gyurov and Tsvetomir Dimitrov</i>	
78. PELTIER MODULE-BASED THERMOREGULATOR FOR LIQUID BIDIRECTIONAL TEMPERATURE CONTROL	327
<i>Kaloyan Ivanov, Ivaylo Belovski and Anatoliy Aleksandrov</i>	
79. APPLICATION OF SWOT ANALYSIS FOR THE SELECTION OF A HYBRID SYSTEM FOR HEATING AND PRODUCTION OF ENERGY AND HOT WATER FOR THE CONDITIONS OF BULGARIA.....	331
<i>Mario Karadjov and Teodora Hristova</i>	
80. APPLICATION OF A METHODOLOGY FOR THE DESIGN AND CONSTRUCTION OF POWER CHOKES FOR LOW VOLTAGE FILTER-COMPENSATING SYSTEMS.....	335
<i>Valentin Gyurov and Milen Duganov</i>	

81. INTEGRATING NARX NEURAL NETWORK WITH K-S TEST FOR ACCURATE PARTIAL DISCHARGE DETECTION IN TRANSFORMERS	339
<i>Abdulla Alabbasi, Mohamed Khalil and Tony McGrath</i>	
82. MULTI-CRITERIA ANALYSIS APPROACHES FOR ENERGY SYSTEM DEVELOPMENT SCENARIOS – REVIEW	346
<i>Kristina Hadzhiyska and Dimo Stoilov</i>	
83. ASSESSMENT OF OPERATIONAL RESERVE REQUIREMENT RESULTING FROM WIND POWER USE IN THE ELECTRIC POWER SYSTEM OF KOSOVO.....	355
<i>Shyqeri Morina and Dimo Stoilov</i>	
84. APPROACHES FOR EFFICIENCY IMPROVEMENT OF THE CHARGING PROCESS IN AN AUTONOMOUS PHOTOVOLTAIC SYSTEM.....	359
<i>Svetlozar Zahariev, Toncho Papanchev and Angel Marinov</i>	
85. APPLICATION OF PROJECT-BASED LEARNING IN THE DIGITAL ELECTRONICS COURSE FOR IMPLEMENTING BOOLEAN FUNCTIONS OF THREE ARGUMENTS WITH MULTIPLEXERS	363
<i>Adriana Borodzhieva and Snezhinka Zaharieva</i>	
86. APPLICATION OF THE VIRTUAL LABORATORY FOR SCHOOLCHILDREN’S FUNCTIONAL LITERACY DEVELOPMENT	367
<i>Olga Alekseyeva, Natalia Alexandrova, Tatyana Chugunova, Daria Burtseva, Roman Petrov, Tatyana Skvortsova, Slavcho Bozhkov, Ivan Milenov and Penko Bozhkov</i>	
87. EXTERNAL ROTOR BLDC MOTOR DESIGN FOR A LIGHT ELECTRIC VEHICLE: 24 SLOT/22 POLE COMBINATION.....	371
<i>Mucahit Soyaslan</i>	
88. IMPLEMENTATION OF A COMPLEX PLC-BASED CONTROL OF THE TECHNOLOGICAL SYSTEMS OF A SPORTS CENTER WITH A SWIMMING POOL.....	375
<i>Bohos Aprahamian and Veselin Vasilev</i>	
89. EFFECT OF THE COLOR OF THE ROOM SURFACES IN A MACHINE HALL ON THE ENERGY EFFICIENCY OF THE LIGHTING INSTALLATION	378
<i>Iva Petrinska</i>	
90. LOW-COST TESTER FOR START-UP AND HOLD-UP VERIFICATION OF ELECTRONIC CONVERTERS	383
<i>Angel Marinov, Svetlozar Zahariev and Toncho Papanchev</i>	
91. MAGNONIC COMMUTATOR ON MAGNETOELECTRIC GRADIENT STRUCTURE FOR ARTIFICIAL NEURAL NETWORKS.....	387
<i>Aleksandr Nikitin, Roman Petrov, Viktor Kiselev, Vasily Misilin, Slavcho Bozhkov, Ivan Milenov and Penko Bozhkov</i>	
92. ON MAGNETIC INDUCTIONS IN A THREE-PHASE SPLIT-PHASE INDUCTION DEVICE	391
<i>Marin Marinov, Georgi Zhelev and Maria Marinova</i>	
93. ELECTRIC OSMOSIS IN HEAT PIPES	395
<i>Yuri Kiliba, Roman Petrov, Ksenia Petrova, Marina Khavanova, Slavcho Bozhkov, Ivan Milenov and Penko Bozhkov</i>	
94. CONCEPT FOR IMPROVING THE LIGHTING ENVIRONMENT AND REDUCING UGR WITH DIMMABLE LED’S SYSTEM IN SPORTS HALL IN LIGHTING CLASS III.....	399
<i>Valentin Gyurov and Zhulieta Vasileva</i>	
95. SOCIAL INEQUILITY AND SUSTAINABLE DEVELOPMENT.....	403
<i>Toshko Petrov</i>	
96. BUSINESS PROCESS REENGINEERING MODEL FOR A WIND PARK.....	406
<i>Svilen Simeonov and Vesela Dicheva</i>	

97. INVESTIGATION OF THE MAGNITUDE OF THE ELECTROMAGNETIC FIELDS IN SPECIFIC WORKING AREAS OF THE ELECTRICAL PERSONNEL ON VESSELS WITH ELECTRIC PROPULSION	410
<i>Emil Barudov, Milena Ivanova, Vyara Vasileva and Miroslava Doneva</i>	
98. MODEL FOR REENGINEERING OF ENTREPRENEURIAL PROCESS IN ELECTRICAL ENGINEERING.....	415
<i>Svilen Simeonov and Vesela Dicheva</i>	
99. TECHNICAL ECONOMIC ANALYSIS OF UTILIZATION OF TRANSFORMERS ALONG A LONG LOW VOLTAGE OVERHEAD POWER LINE.	419
<i>Velichko Atanasov and Dimo Stoilov</i>	
100. SIMULATION AND EXPERIMENTAL STUDY OF STATIC TORQUE CHARACTERISTICS OF A 12/8 THREE-PHASE SRM	423
<i>Dimitar Yankov, Tsvetana Grigorova and Ivan Maradzhiev</i>	

Estimation of Geomagnetically Induced Currents Affect on Power Grid Based on Measurements of Mid-Latitude Geomagnetic Observatories

Kuralay Nurgaliyeva
Department of Physics and technology
al-Farabi Kazakh National University
Institute of Experimental and
Theoretical Physics
Almaty, Kazakhstan
kuralay.nurgaliyeva@kaznu.edu.kz
<https://orcid.org/0000-0002-0696-7277>

Saule Mukasheva
Department of Physics and technology
al-Farabi Kazakh National University
Institute of Experimental and
Theoretical Physics
Almaty, Kazakhstan
snmukasheva@gmail.com
<http://orcid.org/0000-0002-1609-4430>

Alexey Andreyev
Institute of Ionosphere
Almaty, Kazakhstan
alexey.andreyev@ionos.kz
<https://orcid.org/0000-0001-7914-5496>

Olga Sokolova
Institute of Ionosphere
Almaty, Kazakhstan
olgsokolova@yandex.kz
<http://orcid.org/0000-0003-1349-1235>

Nazugum Ussenova
Department of Physics and technology
al-Farabi Kazakh National University
Almaty, Kazakhstan
nazeka976@gmail.com
<https://orcid.org/0009-0005-7158-2380>

Doszhan Zhunisbekov
Tengizchevroil JSC
Atyrau, Kazakhstan
<https://orcid.org/0009-0005-2435-9311>

Abstract — The estimation of geomagnetically induced currents that can affect the power grid system was conducted based on measurements from mid-latitude geomagnetic observatories in this study. To accomplish this, the grid line in the territory of Amaty oblast, Kazakhstan, was selected, and the geophysical conditions in the region were investigated. It was determined that due to geomagnetically active periods, Kazakhstan's energy systems affect by geomagnetically induced currents for a significant duration that depends on the geomagnetic storm value and time of its lasting, with the rate of geomagnetic field changes exceeding 17 nT/min. And the value of the geomagnetically induced currents can vary from fractions of mA to tens of mA.

Keywords — geomagnetically induced currents, overhead power transmission line, geomagnetic storm

I. INTRODUCTION

The release of strong magnetic cloud due to flares at intense Solar periods leads to perturbations in the magnetic field of Earth. These perturbations give rise to varying currents within the ionosphere and magnetosphere. That leads to the negative effect of the occurrence of geomagnetically induced currents (GIC) in conductive ground networks [1-2].

GIC research in the high latitude area began after the disaster pin the Quebec energy system (Canada), which occurred one and a half minutes after the start of a very large magnetic storm (historically referred to as a “great” magnetic storm) on the night of March 13-14, 1989. The storm was caused by powerful proton flares of X-class and M-class on the Sun [3].

Studies of geomagnetically induced currents in Europe, including Sweden [4], Austria [5], Greece [6], and in Brazil [7], Japan [8], South Africa [9], Australia [10], and New Zealand [11], have shown that induced currents, reaching magnitudes of tens of amperes, can occur at middle and low latitudes. A study conducted by Chinese scientists has

revealed that the topology and parameters of the power system are key factors influencing GIC levels at medium and low latitudes, and significant GICs can be observed in these regions [12].

In regions at medium and low latitudes, large geomagnetic fluctuations are caused by increased ring current resulting from intense solar wind flows.

In this research, we estimated the influence of GICs on the power grid by utilizing measurements from mid-latitude geomagnetic observatories.

II. MEASUREMENTS OF MID-LATITUDE GEOMAGNETIC OBSERVATORIES AND GIC ESTIMATION MODEL

The information obtained from four magnetic observatories belonging to the INTERMAGNET network was taken taken into consideration. These observatories include: Alma-Ata Observatory, Kazakhstan located at 43.25°N, 76.92°E, Novosibirsk Observatory located at 54.85°N, 83.23°E, Irkutsk Observatory, Russia located at 52.17°N, 104.45°E, and the Beijing Ming Tombs Observatory, Beijing, China located at 40.3°N, 116.2°E. The locations of the geomagnetic observatories are shown in Figure 1.

The considered area includes overhead power transmission lines, with a total length of 4,216,900 km (via circuits) with voltages across ranging from 0.4 kV to 500 kV. Additionally, there are 12 substations with voltages ranging from 35 kV to 500 kV, with a combined capacity of 4,894.2 MVA (figure 2).

For the estimation of GIC values we've used the one-layer model represented in the [20]:

$$E_x(t) = \frac{1}{\sqrt{\pi\mu\sigma}} \sum_{i=1}^T \left(\frac{1}{\sqrt{t-i}} U[t-i](B_y[i] - B_y[i-1]) \right) \quad (1)$$

where $E_x(t)$ is the electrostatic field x-component, B_y is the geomagnetic field y-component, U is the potential and σ is the electric conductivity of the ground.

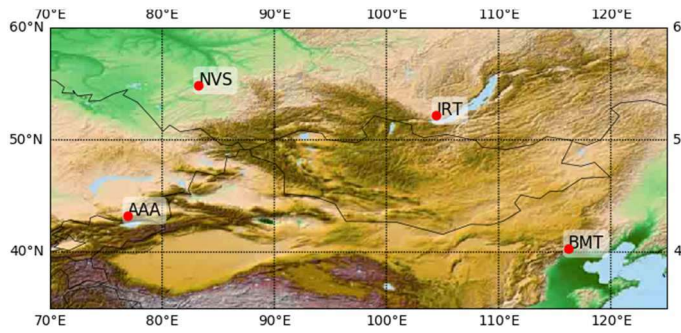


Fig. 1. Location of Alma-Ata Geomagnetic Observatories (AAA), Novosibirsk (NVS), Irkutsk (IRT) and Beijing Ming Tombs, Beijing (BMT).

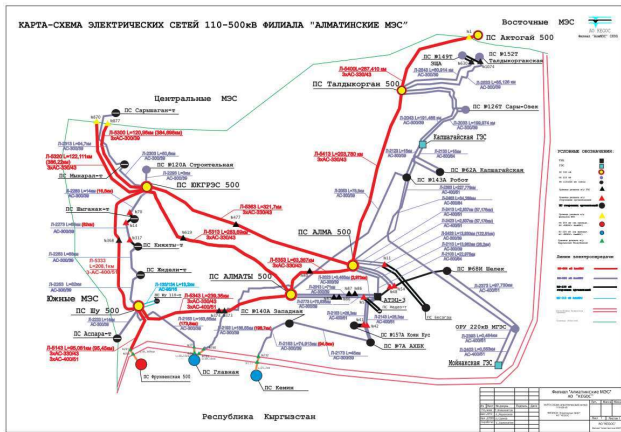


Fig. 2. Overhead power transmission lines.

III. RESULTS AND DISCUSSION

Founded on measurements of the geomagnetic field characteristics, calculations were conducted to determine the value of geomagnetically induced currents. The minute values of the northern X and eastern Y components of the magnetic field were used for these calculations. Based on the data obtained from the four observatories, the induced electromotive force (EMF) values were calculated for very large geomagnetic storms. An analysis was conducted on the fluctuations in the horizontal component (H) of the magnetic field vector and its rate of change over time (dH/dt). Histograms were constructed to illustrate the distribution of $|dH/dt|$ and the directions of H and dH/dt . In Figure 3a, the histograms display the distribution of $|dH/dt|$ based on the data from the selected observatories during the magnetic storm that occurred on May 12-13, 2021. Figure 3b presents histograms of the distribution of dH/dt directions for the same observatories during the same magnetic storm on May 12-13, 2021.

During significant geomagnetic storms, Kazakhstan's energy systems experience prolonged exposure to geomagnetically induced currents, lasting from tens of minutes to several hours. The magnitude of $|dH/dt|$ during these events can reach or exceed 17 nT/min. The estimation of geomagnetically induced currents was done according to the assumption that the self-induction electromotive force (EMF) is directly proportional to the rate of change in

magnetic field strength and computations was based on Eq. (1) and Ohm's law.

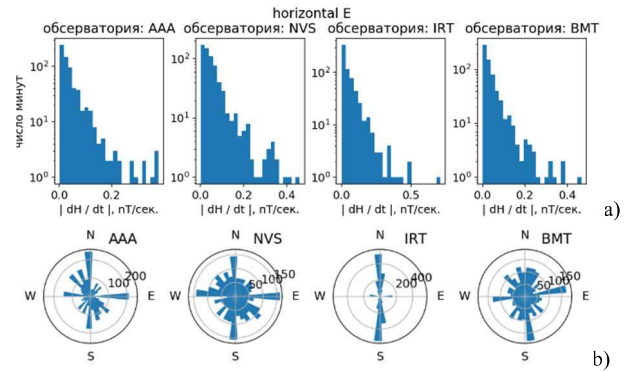


Fig. 3. Histograms of the distribution of the time derivative $|dH/dt|$ (a) and the directions of the time derivative dH/dt (b) during the MBM on May 12-13, 2021

We conducted a study on the geomagnetically induced currents (GICs) resulting from disturbances in the geomagnetic field. The purpose was to assess the potential threat to the electric power system caused by GICs. Alongside geomagnetic variations, geoelectric changes also occur. In closed-circuit power lines spanning long distances, the geoelectric field induces currents. Therefore, calculating GICs involves two steps: determining the geoelectric field and then assessing the corresponding GIC values. In our paper [20], a retrospective analysis of the geophysical conditions from 2016 to 2021 was performed using data from the Alma-Ata geomagnetic observatory. A total of 120 geomagnetic events with disturbances in the geomagnetic field were studied, and GIC values were calculated for all these events. The study examined the characteristics of GIC occurrence at middle latitudes.

In the case of regular geophysical conditions without a magnetic storm, the amplitude of GICs rises maximally up to 0.05 mA (Figure 4-5).

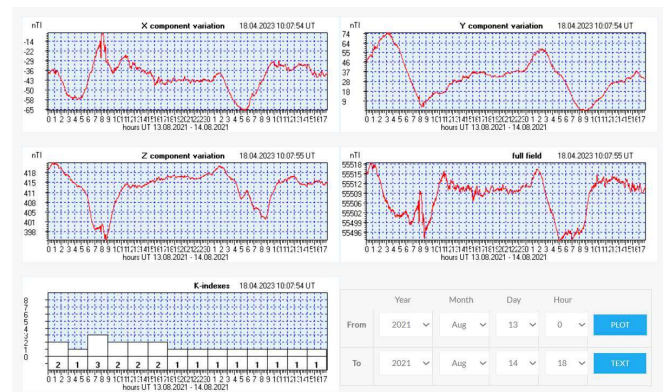


Fig. 4. Variations of geomagnetic field at 2021.08.13 – 2021.08.14

It was observed that during large geomagnetic storms, the amplitude of GICs ranged between $I = 0.4-0.6$ mA (figure 6). For example, during large geomagnetic storm at 2017.09.07 – 2017.09.09 (figure 7) the amplitude of GIC variation rises till 0.4 mA. For average magnetic storms, the amplitude was approximately $I = 0.1-0.3$ mA. The example of geomagnetic field parameters and GIC variation shown in the figures 8-9. During weak magnetic storms, the amplitude values varied between (0.06 - 0.15) mA (figures 10-11).

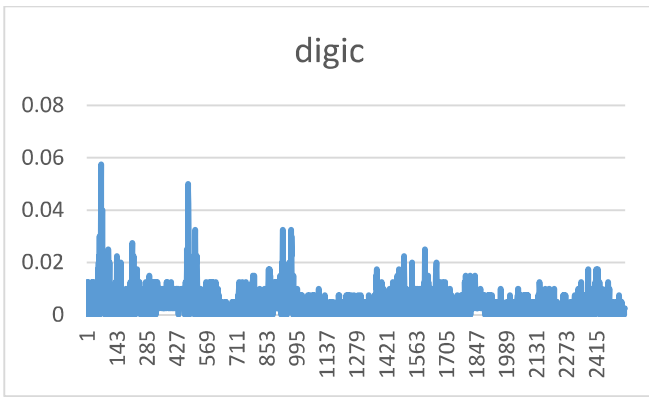


Fig. 5. Variations of GIC induced by geomagnetic field variations at 2021.08.13 – 2021.08.14

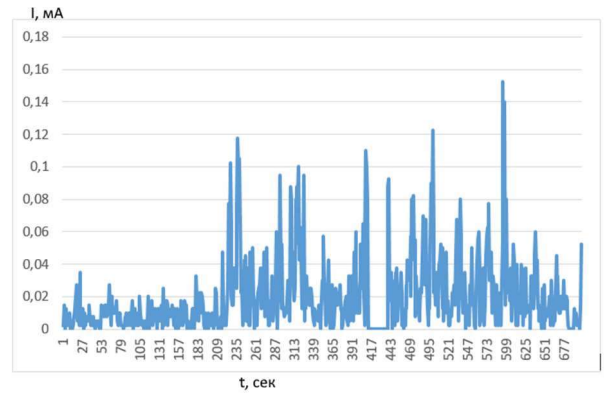


Fig. 9. Variations of GIC induced by geomagnetic field variations during average geomagnetic storm at 2017.05.27 – 2017.05.28

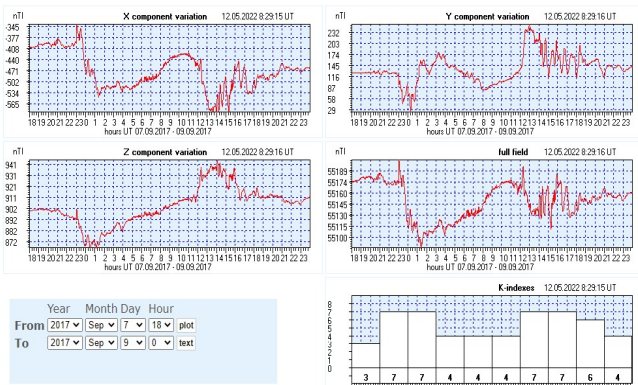


Fig. 6. Variations of geomagnetic field during large geomagnetic storm at 2017.09.07 – 2017.09.09

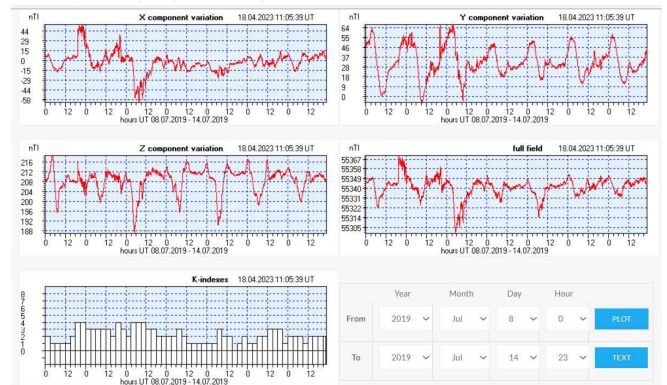


Fig. 10. Variations of geomagnetic field during small geomagnetic storm at 2019.07.08 – 2019.07.09

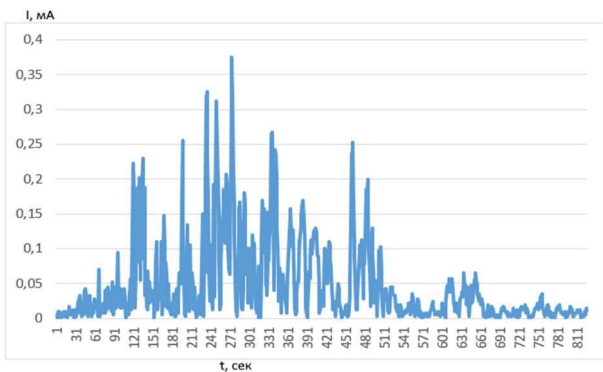


Fig. 7. Variations of GIC induced by geomagnetic field variations during large geomagnetic storm at 2017.09.07 – 2017.09.09

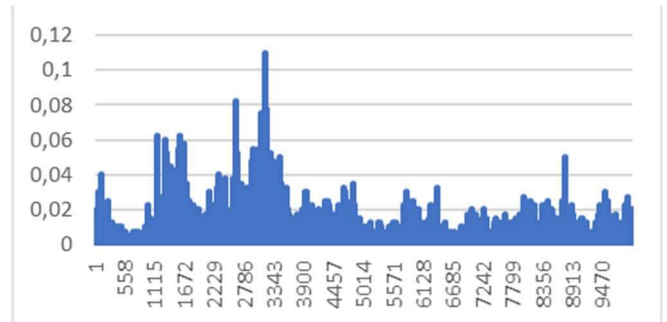


Fig. 11. Variations of GIC induced by geomagnetic field variations during small geomagnetic storm at 2019.07.08 – 2019.07.09

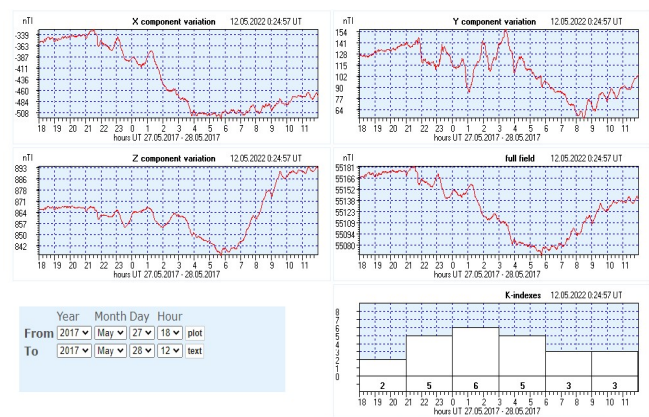


Fig. 8. Variations of geomagnetic field during average geomagnetic storm at 2017.05.27 – 2017.05.28

In cases of storms with sudden onsets at 2018.08.25 – 2018.08.26 (figure 12), the induced current amplitude occasionally increased up to $I = 0.75$ mA (figure 13).

Generally, the value of GICs is dependent on the intensity of the geomagnetic storm, although there are some exceptions. For instance, a storm with a sudden onset, classified as a weak geomagnetic storm according to the planetary index, exhibited a higher GIC value than during a large geomagnetic storm. The detailed estimations provided by the authors in their article [13], it shown there that the GIC values can range from fractions of mA to tens of mA.

During extremely severe geomagnetic storms, the energy systems in Kazakhstan experience prolonged exposure to geomagnetically induced currents (GIC) that can last from tens of minutes to several hours. This occurs when the

magnitude of the rate of change in the horizontal component of the magnetic field (dH/dt) reaches 17nT/min or higher.

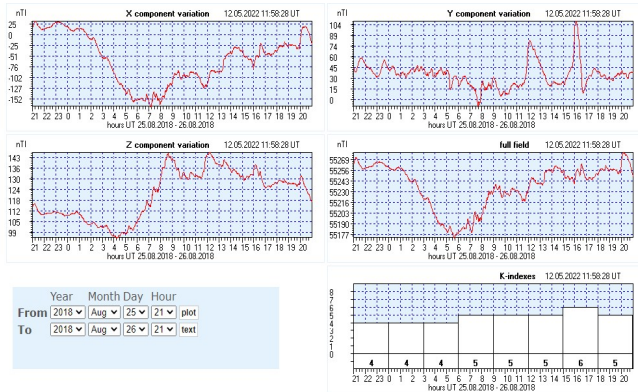


Fig. 12. Variations of geomagnetic field during storm with sudden onsets at 2018.08.25 – 2018.08.26

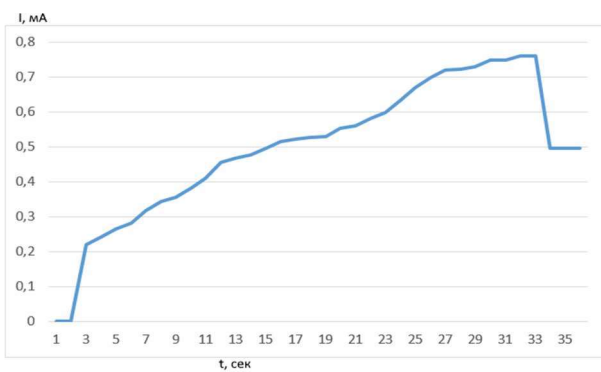


Fig. 13. Variations of GIC induced by geomagnetic field variations during storm with sudden onsets at 2018.08.25 – 2018.08.26

The estimation of GIC is based on the calculation that the self-induction electromotive force (EMF) is directly proportional to the rate of change in magnetic field strength. According to estimations done by authors, the GIC value can vary from hundreds of fractions of mA to tens of mA. For more accurate calculations, it is essential to consider factors such as the electrical system's topology, the nature of the underlying surface, and other elements that influence the susceptibility of individual components within the power system.

ACKNOWLEDGMENT

The work was carried out with the financial support of the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan grant project AP09259554.

REFERENCES

- [1] G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," *Phil. Trans. Roy. Soc. London*, vol. A247, pp. 529–551, April 1955. (references) Gannon J. L., Swidinsky A., Xu Zh. Geomagnetically Induced Currents from the Sun to the Power Grid // *Geophysical Monograph Series: John Wiley & Sons*, ISBN: 978-1-119-43438-2, 2019. -P.246-256. <https://doi.org/10.1002/9781119434412.ch2>
- [2] D.T.O. Oyedokun, P.J.Cilliers *Classical and Recent Aspects of Power System Optimization: Chapter 16 - Geomagnetically Induced Currents: A Threat to Modern Power Systems.*—Academic Press, 2018, P. 421-462. <https://doi.org/10.1016/B978-0-12-812441-3.00016-1>.
- [3] L. Bolduc, P Langlois., D. Boteler, R. Pirjola. A study of geoelectromagnetic disturbances in Quebec, 2. Detailed analysis of a large event // *IEEE Trans. Power Delivery.*—2000. -Vol. 15. -P. 272.
- [4] M. Wik, A. Viljanen, R. Pirjola, A.Pulkkinen, P. Wintoft, H.Lundstedt. Calculation of geomagnetically induced currents in the 400 kV power grid southern Sweden // *Space Weather.* -2008. -Vol. 6. -P. 07005, <https://doi.org/10.1029/2007SW000343>
- [5] M. Torta, S. Marsal, M. Quintana. Assessing the hazard from geomagnetically induced currents to the entire highvoltage power network in Spain // *Earth Planets Space.* -2014. -P. 66-87. <https://doi.org/10.1186/1880-5981-66-87> (дата обращения 2021-05-27)
- [6] R. L. Bailey, T. S. Halbedl, I. Schattauer, Al. Römer , G. Achleitner, C. D. Beggan , V. Wetztergom, R. Egli, R. Leonhardt. Modelling geomagnetically induced currents in midlatitude Central Europe using a thin-sheet approach // *Ann. Geophys.* - 2017. -Vol. 35. -P. 751-761. DOI: [org/10.5194/angeo-35-751-2017](https://doi.org/10.5194/angeo-35-751-2017)
- [7] C.da Silva Barbosa, G. A Hartmann, K.J. Pinheiro. Numerical modeling of geomagnetically induced currents in a Brazilian transmission line // *Adv. Space Res.* -2015. -Vol.44. -P. 1168-1179. <https://doi.org/10.1016/j.asr.2014.11.008>.
- [8] S. Watari, M.Kunitake, K. Kitamura, T. Hori, T. Kikuchi, K. Shiokawa, N. Nishitani, R. Kataoka, Y. Kamide, T. Aso, Y. Watanabe, Y. Tsuneta. Measurements of geomagnetically induced current in a power grid in Hokkaido // *Japan, Space Weather.* -2009. -N 7, S03002. <https://doi.org/10.1029/2008SW000417>
- [9] E. Matandirotya, P. J. Cilliers, R. R. Van Zyl. Modeling geomagnetically induced currents in the South African power transmission network using the finite element method // *Space Weather.* -2015. -N 13. -P. 185-195. <https://doi.org/10.1002/2014SW001135>.
- [10] R. A. Marshall, E. A. Smith, M. J. Francis, C. L. Waters, M. D. Sciffer. A preliminary risk assessment of the Australian region power network to space weather // *Space Weather.* -2011. -N 9, S10004. <https://doi.org/10.1029/2011SW000685>
- [11] J. Beland, K.Small. Space weather effects on power transmission systems: The cases of Hydro-Québec and Transpower New Zealand Ltd., in: *Effects of space weather on technology infrastructure* // Springer, 2005. -P. 287-299.
- [12] C. M. Liu, L.G. Liu, R. Pirjola, Z.Z. Wang. Calculation of geomagnetically induced currents in mid- to low-latitude power grids based on the plane wave method: A preliminary case study // *Space Weather.* -2009. -Vol. 7. -P. S04005, doi:10.1029/2008SW000439.
- [13] K. Nurgaliyeva. Investigation of the influence of space weather on the occurrence of geinduction currents in the middle latitudes // *Recent Contributions to Physics.* No1(84). 2023, p.48-55 <https://doi.org/10.26577/RCPH.2023.v84.i1.06>