N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
PHYSICO-MATHEMATICAL SERIES
ISSN 1991-346X **https://doi.org/10.32014/2019.2518-1726.51**
Volume 4, Number 326 (2019), 129 – 134

A.F. Yakovets[1], A. Jahanshir[2], G.I. Gordienko[1], B.T. Zhumabayev[1], Yu.G. Litvinov[1], N. Abdrakhmanov[3]

[1]«Institute of Ionosphere» JSC «NCSRT», Almaty, Kazakhstan;
[2]Buein Zahra Technical University, Iran;
[3]Korkyt ata's Kysylorda State University, Kysylorda, Kazakhstan
artyak40@mail.ru

STATISTICS OF VARIATION RANGE OF F2- LAYER MAXIMUM HEIGHT OF THE IONOSPHERE

Abstract. The statistics of the nights when the ionosphere was sounded at the Institute of the Ionosphere in 2009–2016, and the nights during which the large scale traveling ionospheric disturbances (LS TIDs) were observed, were presented. Out of 1454 sessions of nighttime observations of the ionosphere, LS TIDs were observed in 185 sessions. The features of atmospheric and magnetospheric LS TIDs are found: a) high coherence of variations of critical frequencies and virtual heights ($h'(t)$), b) an increase in the amplitude of variations of $h'(t)$ with an increase in the sounding frequency, c) phase delay of variations of $h'(t)$ at lower frequencies relative to variations at high frequencies. A method has been developed for estimating the magnitude of the peak to peak variations in the height of the F-layer maximum, in terms of the range of variations of the virtual reflection height of the sounding signal $h'(t)$ at the maximum frequency reflected from the ionosphere. Distributions of the magnitude of the maximum height variations are obtained for magnetically quiet and magnetically active observation conditions of the LS TIDs. It was found that the maximum probabilities of the magnitude of peak to peak lie in the range of 40-50 km for a disturbed and 30-50 km for a quiet magnetic field.

Key words: ionosphere, vertical sounding, height of F layer maximum.

Introduction

It is known that large-scale traveling ionospheric disturbances (LS TIDs) are manifestations of atmospheric gravity waves (AGWs) generated in polar regions during geomagnetic storms [1], when the rapid amplification of polar electrojets leads to local atmosphere heating. The process of rapid expansion and subsequent compression of the atmosphere creates atmospheric gravity waves that propagate to the equator and generate the LS TIDs on its way. A number of observations have shown that the LS TIDs can also persist during magnetically quiet periods [2, 3]. The propagation of AGW in the neutral atmosphere and their ionospheric manifestations (LS TIDs) have been studied both experimentally and theoretically for many years. The results of these studies are presented in a series of reviews [1, 4, 5].

AGW at middle latitudes have a wavelength greater than ~ 1000 km. For such a wave, the motion of a neutral gas at the heights of the F-layer is a horizontal wind blowing south along the meridian when half of the wave passes over the observation point and north when the next half-wave passes. Plasma in the F-layer of the ionosphere is involved in the movement due to collisions of neutrals with ions. The plasma in the F-layer is magnetized and, therefore, can only move along magnetic lines of force. This movement is due to the component of the neutral wind, directed along the magnetic field. A neutral wind blowing towards the equator and the pole pushes the plasma along the magnetic field lines up and down, respectively, leading to periodic fluctuations in the height of the F-layer maximum. Information on oscillations of the meridional wind caused by the passage of AGW was obtained by us in [6, 7], in which a method was developed for processing data of the vertical sounding of the ionosphere and finding the distribution of the magnitude of variations in the height of the F-layer maximum has been done. The range of variations was estimated from the height profile of the electron concentration obtained as a result of laborious calculations. This paper proposes a simple method for estimating the range of variations from the initial ionogram data and presents the results obtained for the period 2009–2016.

Description of the equipment and analysis of the results of observations.

Nighttime observations of the LS TIDs in the *F*-layer of the ionosphere were carried out at the Institute of the Ionosphere (Alma-Ata 76 ° 55'E, 43 ° 15'N) on a digital ionosonde PARUS associated with a computer intended for collecting, storing and processing ionograms in digital form. The information necessary for calculating the various parameters of the LS TIDs was read from the ionograms by the semi-automatic method with the participation of an experienced operator. In [8], it was shown that such a method has a greater, as compared with the automatic method, reading accuracy of ionospheric parameters with ionograms and a large statistical yield of ionograms suitable for processing. The ionosphere was sounded every 5 min. The ionograms allow reading the values of the virtual reflection heights $h'(t)$ of the radio signal at a number of fixed operating frequencies and critical frequencies ($f_{o,x}F$). 1454 nighttime observations were carried out for the period 2009 - 2016, while 185 nights were characterized by wave activity associated with the LS TIDs.

The nights characterized by wave activity were divided into two groups according to the minimum value of the Dst index, which took place on a time interval beginning a few hours before the start of the observation session and ending at the end of the session. They represented observations with moderate and high geomagnetic activity (Dst ≤ - 40 nT) and low magnetic activity (Dst> - 40 nT). A typical example of the behavior of the *F*-layer parameters for such nights is shown in Fig. 1.

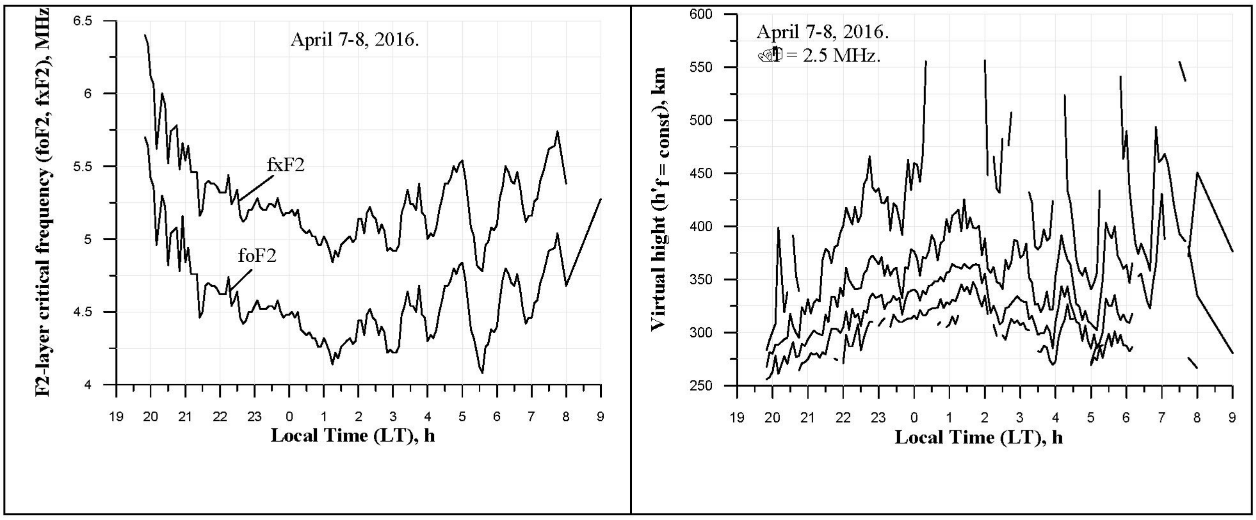

Figure 1 - Example of stochastic (LT = 20.00-01.30) and quasi-periodic (LT = 01.30-08.00) variations of critical frequencies (left panel) and effective heights of reflection from the ionosphere on a series of sounding frequencies (right panel).

Figure 1 shows the variations of critical frequencies (left panel) and operating altitudes (right panel) at night of April 7–8, 2016. Visual analysis allows us to conclude that in the first half of the night the critical frequencies decreased because the Sun, which represents the main source of ionizing radiation, did not illuminate the thermosphere on ionospheric altitudes. At the same time, the virtual reflection heights of the radio signal increased. Around 01.30, quasi-periodic variations of $f_{o,x}F$ and $h'(t)$ began at a number of sounding frequencies with an average period of ~ 1.5 h. Such characteristics of parameter variations as their high coherence and phase delays $h'(t)$ at lower frequencies with respect to variations on at high frequencies, allow to conclude that the variations represent LS TIDs caused by the propogation of AGW.

Critical frequencies and virtual heights are directly read from ionograms by the operator, but they do not allow to obtain data on variations in the height of the layer maximum. To consider the possible connection, we compared the parameters of variations obtained from the altitude ionization profiles (Fig. 2, left panel) with the parameters of variations $h'(t)$ (Fig. 2, right panel). The left panel shows variations in the height of the *F*-layer maximum (h_mF), the base of the layer ($h_{bot}F$), the half-thickness of the layer (Δh), and the critical frequency f_0F. We are only interested in h_mF. It follows from the figure that on this night three waves with maxima were clearly traced, both for variations h_mF and for variations $h'(t)$, occurring at the times of 21:00, 23:30 and 01:30.

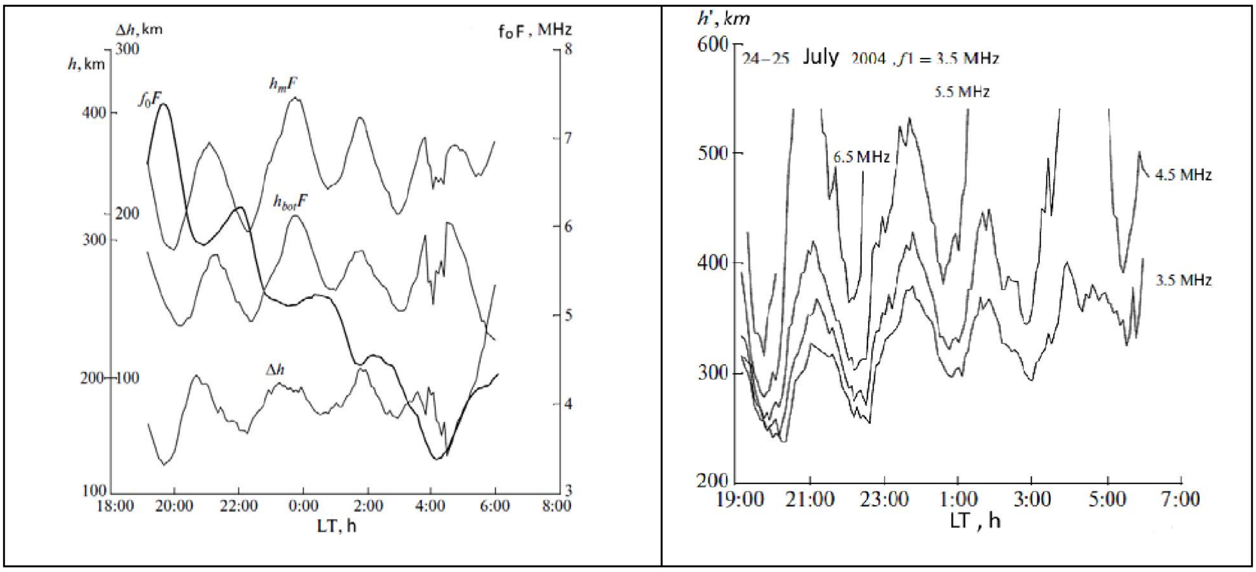

Figure 2 - Variations of the parameters of the ionosphere, calculated from the height profiles of the electron concentration (left panel) and variations of the virtual heights on a series of sounding frequencies (right panel) during the passage of atmospheric gravity waves

Let's turn to the right panel of the figure. It is seen that the variations of $h'(t)$ at the upper frequencies have discontinuities of various lengths. These discontinuities are due to the temporary behavior of the critical frequency (left panel). When the critical frequency becomes less than one or another frequency indicated on the right panel, the reflection at this frequency does not occur, and there are gaps in the behavior of $h'(t)$. It follows from the figure that with an increase in the working frequency, the range of variations increases. Tab. 1 shows the magnitude of variations for the height of the layer maximum (Δh_mF) and the virtual heights ($\Delta h'(t)$) for the three recorded waves. In this case, $\Delta h'_1$ refers to variations at a frequency of 3.5 MHz, $\Delta h'_2$ refers to variations at a frequency of 4.5 MHz, $\Delta h'_3$ refers to variations at a frequency of 5.5 MHz. The last frequency listed in the table for each wave corresponds to the maximum frequency that is still reflected from the ionosphere.

The next frequency is already experiencing breaks. For example, for waves 1, 2, the last frequency is 5.5 MHz, and for wave 3, this frequency is 4.5 MHz. Comparing the values given in the table, we come to the conclusion that the range of variations at the last frequency is about 2 times greater than the range of variations in the height of the layer maximum. This pattern was also observed for the other reviewed sessions of observations of the LS TIDs. Therefore, when processing a large statistical material, we used this ratio.

Table 1

LT	Δh_m(km)	$\Delta h'_1$(km)	$\Delta h'_2$(km)	$\Delta h'_3$(km)
21:00	70	75	95	130
23:30	82	100	110	165
01:30	60	70	115	

Using this ratio, ΔhmF were calculated for all sessions with LS TIDs. In fig. Figure 3 shows the histograms of the distribution of the range of variations of the LS TIDs with low (left panel) and high (right panel) magnetic activity. The maximum probabilities ΔhmF lie in the range of 40-50 km for a disturbed and 30-50 km for a quiet magnetic field.

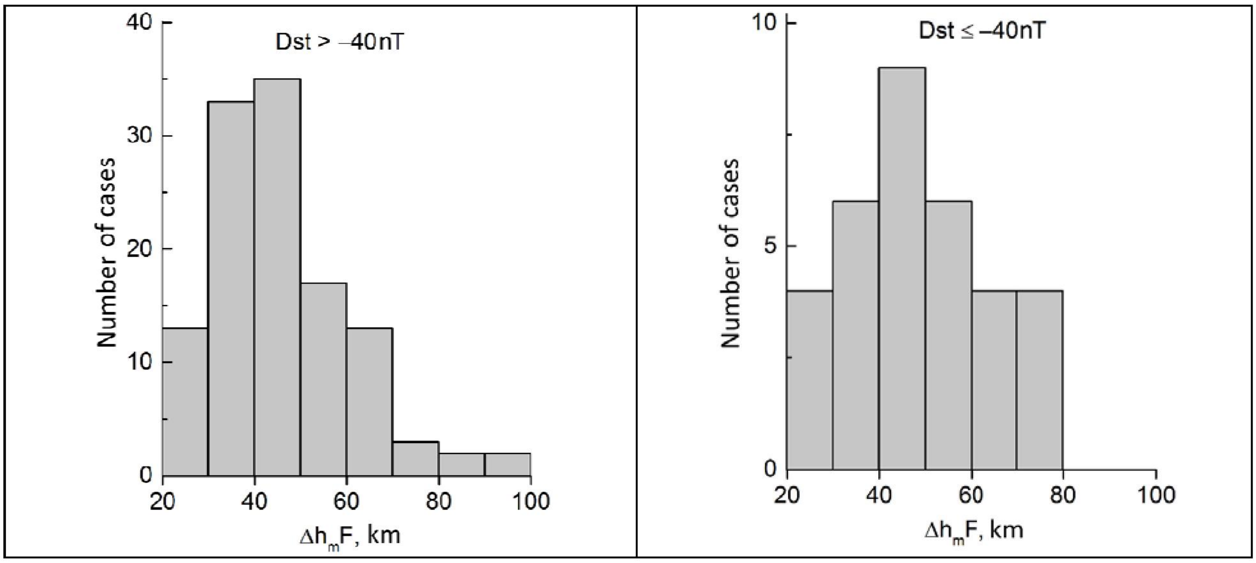

Figure 3 - Histograms of the distribution of the amplitude of variations of the LS TIDs with low (left panel) and high (right panel) magnetic activity

We analyzed all observation sessions, when quasi-periodic variations of ionospheric parameters were recorded. It was found that LS TIDs generated at low magnetic activity have the same properties as LS TIDs of magnetospheric origin, namely: a) high coherence of variations of critical frequencies and virtual heights ($h'(t)$) at heights covering the lower part of the F-layer, b) an increase in the amplitude of the variations $h'(t)$ with an increase in the sounding frequency; c) a phase delay of the variations $h'(t)$ at lower frequencies relative to variations at high frequencies. Thus, we came to the conclusion that the internal structure of the LS TIDs is the same for different sources of disturbances.

Conclusion

Thus, statistics was calculated for the nights when the ionosphere was frequently sounded at the Institute of the Ionosphere in 2009–2016, and for the nights during which traveling ionospheric disturbances were observed. Out of 1,454 sessions of nighttime observations of the ionosphere, 185 sessions with the LS TIDs were observed. The signs of atmospheric and magnetospheric origins of the LS TIDs are found: a) high coherence of variations of critical frequencies and virtual heights ($h'(t)$), b) an increase in the amplitude of variations $h'(t)$ with an increase in the sounding frequency, c) a phase delay of variations $h'(t)$ at lower frequencies relative to variations at high frequencies. A method has been developed for estimating the magnitude of the amplitude of variations in the height of the F-layer maximum, in terms of the amplitude of variations of the virtual reflection height of the sounding signal $h'(t)$ at certain sounding frequencies. Distributions of the magnitude of the amplitude height variations are obtained for magnetically quiet and magnetically active observation conditions of the LS TIDs.

The work was carried out in accordance with RBP-008 "Development of space technologies for monitoring and forecasting natural resources, technogenic environmental changes, creation of space technology and ground-based space infrastructure, research of long-distance and near-space objects" under the theme "Creation of a system of diagnostics and forecast of space weather for analysis and forecasting of conditions of functioning of space vehicles, navigation and communication systems (2018-2020), registration number (RN) 0118PK00800.

А.Ф. Яковец[1], А. Жаханшир[2], Г.И. Гордиенко[1],
Б.Т. Жумабаев[1], Ю.Г. Литвинов[1], Н. Абдрахманов[3]

[1]ЕЖШС «Ионосфера институты» «ҰҒЗТО» АҚ, Алматы, Қазақстан
[2]Буин Захра техникалық университеті, Иран
[3]Қорқыт Ата атындағы Қызылорда мемлекеттік университеті, Қызылорда, Қазақстан

ИОНОСФЕРАДАҒЫ F2- ҚАБАТЫНЫҢ ВАРИАЦИЯ АУҚЫМЫНЫҢ МАКСИМАЛДЫ БИІКТІГІН АЙҚЫНДАУ СТАТИСТИКАСЫ

Аннотация. Ионосфера институтында 2009-2016 жылдары жүргізілген ионосфераның жиі түндерін барлап байқау көрсетілген және де кең көлемді жылжымалы ионосфералық бұзылулар (КЖИБ) байқалған түндердің статистикасы ұсынылған. Ионосфераның түнгі бақылауларының 1454 сеансынан 185 (КЖИБ) сеансы байқалды. Кең көлемді жылжымалы ионосфералық бұзылулардың атмосфералық және магнитосфералық шығу белгілері анықталды: а) сыни жиіліктер мен биіктіктердің (*h'(t)*) қолданыстағы вариацияларының жоғары келісімділігі, б) вариация амплитудасының артуы *h'(t)* барлап байқау жиілігінің ұлғаюымен, в) жоғары жиіліктердегі вариацияларға қатысты төменгі жиіліктердегі вариацияларының *h'(t)* фазалық кешігуі. Ионосферадан көрінетін максималды жиіліктегі сигналының *h'(t)* тиімді көрсетілу биіктігіндегі вариация ауқымы бойынша, F-қабатының максималды биіктігіндегі вариация шамасын бағалау үшін әдіс әзірленді. Кең көлемді жылжымалы ионосфералық бұзылулардың магниттік тыныштықты және магниттік белсенді бақылау жағдайында, ауқымы бойынша максималды биіктік вариация шамаларының таралуы алынды. Максималды ықтималдығы бұзылған ауқым шамасы 40-50 км және тыныш магнит өрісі үшін 30-50 км болатындығы анықталды.

Түйін сөздер: ионосфера, тік барлап байқау, F2- қабатының максималды биіктігі

А.Ф. Яковец[1], А. Жаханшир[2], Г.И. Гордиенко[1],
Б.Т. Жумабаев[1], Ю.Г. Литвинов[1], Н. Абдрахманов[3]

[1]ДТОО «Институт ионосферы» АО «НЦКИТ», Алматы, Казахстан
[2]Буин Захра Технический Университет, Иран,
[3]Кызылординский государственный университет им. Коркыт ата, Кызылорда

СТАТИСТИКА РАЗМАХА ВАРИАЦИЙ ВЫСОТЫ МАКСИМУМА F2- СЛОЯ ИОНОСФЕРЫ

Аннотация. Представлена статистика ночей, когда проводилось учащенное зондирование ионосферы в Институте ионосферы в 2009-2016 годы, и ночей, в течение которых наблюдались крупномасштабные перемещающиеся ионосферные возмущения (КМПИВ). Из 1454 сеансов ночных наблюдений ионосферы в 185 сеансах наблюдались КМПИВ. Найдены признаки КМПИВ атмосферного и магнитосферного происхождения: а) высокая когерентность вариаций критических частот и действующих высот (*h'(t)*), б) увеличение амплитуды вариаций *h'(t)* с увеличением зондирующей частоты, в) фазовое запаздывание вариаций *h'(t)* на меньших частотах относительно вариаций на больших частотах. Разработан способ оценки величины размаха вариаций высоты максимума F-слоя, по размаху вариаций действующей высоты отражения зондирующего сигнала *h'(t)* на максимальной частоте, отражающейся от ионосферы. Получены распределения размаха вариаций высоты максимума для магнитоспокойных и магнитоактивных условий наблюдения КМПИВ. Найдено, что максимальные вероятности величины размаха лежат в диапазоне 40-50 км для возмущенного и 30-50 км для спокойного магнитного поля.

Ключевые слова: ионосфера, вертикальное зондирование, высота максимума F2-слоя

Information about authors:

Yakovets Arthur Fedorovich - cand. of phys.-mat. sciences, Leading Researcher, Institute of the Ionosphere JSC "NCSR", Almaty, artyak40@mail.ru. 1) The author made a significant contribution to the research concept, data analysis and interpretation, 2) the author wrote the first version of the article, 3) the author approved the final version of the article before submitting it for publication;

Arezu Jahanshir - PhD in Teoretical Physics and Mathematics, Buein Zahra Technical University, Iran, jahanshir@bzte.ac.ir 1) The author made a significant contribution to the concept and design of the study, the interpretation of data, 2) the author made a critical review of the article for important intellectual content, 3) the author approved the final version of the article before submitting it for publication;

Gordienko Galina Ivanovna - cand. of phys.-mat. sciences, Leading Researcher, Institute of the Ionosphere JSC "NCSR", Almaty, ggordienko@mail.ru. 1) The author made a significant contribution to the research concept, data acquisition and interpretation, 2) the author wrote the first version of the article; 3) the author approved the final version of the article before submitting it for publication;

Zhumabayev Beybit Tenelovich - cand. of phys.-mat. sciences, a head of laboratory, Institute of the Ionosphere JSC "NCSR", Almaty, beibit.zhu@mail.ru. 1) The author made a significant contribution to the study design, data acquisition, 2) the author wrote the first version of the article, 3) the author approved the final version of the article before submitting it for publication;

Litvinov Yurii Georgievich, cand. cand. of phys.-mat. sciences, senior researcher, Institute of the Ionosphere, JSC "NCSR", Almaty, yurii-litvinov@mail.ru. 1) The author made a significant contribution to the acquisition of data and their analysis, 2) the author made a critical review of the article for important intellectual content, 3) the author approved the final version of the article before submitting it for publication;

Abdrakhmanov Nurtaza, cand. cand. of phys.-mat. sciences, senior researcher, Kyzylorda State University. Korkyt ata, Kyzylorda, abdrakhmanov.48@mail.ru. 1) The author made a significant contribution to data acquisition and interpretation, 2) the author made a critical review of the article for important intellectual content, 3) the author approved the final version of the article before submitting it for publication

REFERENCES

[1] Hunsucker R.D. Atmospheric gravity waves generated in the high latitude ionosphere: A review // Rev. Geophys. V. 20. № 2. P. 293–315. 1982.

[2] Tsugawa T., Saito A., Otsuka Y. A statistical study of large-scale traveling ionospheric disturbances using the GPS network in Japan // J. Geophys. Res. V. 109. № A06302, doi:10.1029/2003JA010302. 2004.

[3] Hawlitschka S. Travelling ionospheric disturbances (TIDs) and tides observed by a super-resolution HF direction finding system // J. Atmos. Solar-Terr. Phys. V. 68. № 3–5. P. 568–577. doi:10.1016/j.jastp.2005.03.022. 2006.

[4] Yeh K.C., Liu C.H. Acoustic-gravity waves in the upper atmosphere // Rev. Geophys. Space Phys. V. 12. P. 193–216. 1974.

[5] Hocke K., Schlegel K. A review of atmospheric gravity waves and traveling ionospheric disturbances: 1982–1995 // Ann. Geophysicae. V. 14. № 9. P. 917–940. 1996.

[6] A. F. Yakovets, V. V. Vodyannikov, G. I. Gordienko, and Yu. G. Litvinov. Thermospheric Wind Oscillations during the Propagation of Large-Scale Traveling Ionospheric Disturbances// Geomagnetism and Aeronomy, 2014, Vol. 54, No. 4, pp. 480–487.

[7] A. F. Yakovets, G. I. Gordienko, B.T. Zhumabaev and Yu. G. Litvinov. Comparison of altitude profiles of amplitude of two types of F2-layer ionospheric disturbances// News of the National Academy of Sciences of the Republic of Kazakhstan. Physico-Mathematical Series (In Russ) 2018, No 4, P. 79-84.

[8] Stankov S.M., Jodogne J.C., Kutiev I., Stegen K., Warnant R. Evaluation of automatic ionogram scaling for use in real-time ionospheric density profile specification: Dourbes DGS-256/ARTIST-4 performance // Ann. Geophys. V. 55. № 2. P. 283–291. doi:10.4401/ag-4976. 2012.

N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
PHYSICO-MATHEMATICAL SERIES
ISSN 1991-346X https://doi.org/10.32014/2019.2518-1726.52
Volume 4, Number 326 (2019), 135 – 142

UDC 004.9:519
IRSTI 20.53.00

M. Kalimoldayev, M. Akhmetzhanov, M. Kunelbayev

Institute Information and Computational Technologies CS MES RK,
Almaty, Republic of Kazakhstan

DEVELOPMENT AND RESEARCH OF A MATHEMATICAL MODEL OF A SOLAR PHOTO CONVERTER WITH AN INVERTER FOR CONVERTING DIRECT CURRENT TO ALTERNATING VOLTAGE

Abstract. This article presents a mathematical model of photovoltaic systems. For the analysis of energy processes in autonomous power transmission systems, it is now advisable to use computer simulation methods. The use of a simulation model makes it possible to provide an energy balance in an autonomous power transmission system with specific energy characteristics of ground and buffer sources of energy and a time scale from the power consumption of the load. This allows you to influence the energy characteristics of transmission systems to ensure the energy balance in the system in terms of temporary changes in the energy characteristics of energy sources, as well as the impact on the energy characteristics of the systems of transmission parameters such as solar energy. lighting, temperature, time of year, etc. This model is described by the current-voltage characteristic (CVC) at a given temperature, and the lighting conditions are the basis for calculating the parameters of the photoelectric energy in a wok. A new inverter was also designed and researched to convert direct current into alternating voltage, which allowed saving from 18.5% to 35.19% of expensive solar photo converters.
Keywords: solar cell; the current-voltage characteristics; mathematical model; MatLab.

1.Introduction

Solar cells in the production of electricity from renewable energy sources, is now developing rapidly and soon will be increased overall use [1]. For example, small solar cells used in watches, calculators, small toys, radios and portable TVs. While large objects are combined into modules and are used to supply the power system [2,3].

A solar cell is an electrical device that converts light energy into electricity using the photoelectric effect. The main material used for the production of solar cells is silicon.

I. The design and manufacture of silicon solar battery Large blocks of molten silicon carefully cooled and solidified is made from cast ingots of polycrystalline silicon square. Polycrystalline silicon is less costly than single crystal and are less effective [4,3,5]. Solar battery consists of the following elements [6,7,8].

- Silicon wafer (mono- or polycrystalline) with a p-n junctions on the surface.
- Front and back contact; front contact must have the correct shape to make the most of the incident radiation.
- Antireflection layer - cover the front surface. There are three major types of solar cells.
- Single crystal formed on a silicon crystal with a homogeneous structure. The basis for the formation of cells that are suitable silicon-sized blocks.
- They are cut into plates whose thickness is about 0.3 mm. Photovoltaic cells achieve the highest levels of performance and life [4,6].
- Polycrystalline are comprised of many small grains of silicon. These solar cells are less efficient than single crystal. The production process is simpler and have lower rates [4,6].