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Contents

Approximation of the frequency dependence of the equivalent resistance of schottky contacts

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Abstract: Approximation of dependence of equivalent resistance of successive substitution scheme of metal-semiconductor Schottky`s contacts and take into account capacitance and resistance of contact and volume are proposed. Approximation curve represents a broken line.

Keywords: Schottky`s contact; Equivalent resistance; Approximation of frequency dependence; Capacitance of contact; Capacitance of volume; Resistance of volume; Resistance of contact.

1. Introduction

Schottky barrier structures are an integral part of a number of electronic elements, such as Schottky diodes and photodiodes, Schottky gate transistors, and some others. An analysis of the frequency dependences of the capacitance, dielectric losses, and electrical conductivity of such elements [1, 2] necessitates the use of various kinds of models. In this regard, issues related to the development of mathematical, graphical and graph-analytical models of structures with a Schottky barrier are of considerable interest to developers of microelectronic technology. A structure with a Schottky barrier can be represented [3] as a series connection of capacitance C1 and resistance R1 of the contact with capacitance C2 and volume resistance R2 (Fig. 1, inset). To compare the results of measuring the capacitance and resistance of a structure with a Schottky barrier with theoretical results, it is necessary to represent the indicated structure in the form of equivalent capacitance Ceq and resistance Req connected in series or in parallel. Further, using the relations connecting Seq and Req of a series equivalent circuit with C_1, R_1 and C_2, R_2, it is possible to plot the frequency dependence curves of the equivalent capacitance and resistance. This model is widely used for research as the classical Simmons model [3,4]. However, the construction of curves of capacitance and resistance versus frequency according to the above ratios is a rather cumbersome task.

In [5], a simplified graphical-analytical model of structures with a Schottky barrier was developed, approximating the real curves of the dependences of the equivalent capacitance and resistance of a series equivalent circuit on frequency, in which the contact resistance is not taken into account, which makes it possible to simplify the analysis and calculation of structures with a Schottky barrier. This model is valid for structures with high contact resistance (G1=0). The use of such a simplified model in the case when the contact resistance is sufficiently small and its influence cannot be neglected leads to inaccurate results in the analysis and calculation of structures with a Schottky barrier.

The purpose of this work is to approximate the dependence of the equivalent resistance of a series equivalent circuit of metal-semiconductor contacts on frequency, taking into account the capacitance and resistance of the contact and volume, and to construct the corresponding approximating curve, which makes it possible to increase the reliability of the analysis and calculation of structures with a Schottky barrier.

The relevance of the proposed model and interest in it is growing in connection with new promising studies of such nanomaterials [6-8] as carbon, graphene, gadolinium, etc., on the basis of which such effective elements and devices of micro- and nanoelectronics as negatrons [9], nanotubes [10,11], solar panels [12], hybrid energy systems [13-17], etc. have already been created and continue to be actively developed.

2. Experimental details

In the analysis, we assume that the resistance and capacitance of the contact and the volume of structures with a Schottky barrier do not depend on frequency.

Let us write down the relation connecting Reqv of the sequential equivalent circuit with C_1, R_1 and C_2, R_2,

$$R_{eqv} = \frac{(G_1+G_2)G_1G_2+\omega^2\left(C_1^2G_2+C_2^2G_1\right)}{\left(G_1G_2-\omega^2C_1C_2\right)^2+\omega^2\left(C_1G_2+C_2G_1\right)^2} \quad (1)$$

Consider the dependence of the equivalent resistance on frequency. Expression (1) can be represented as

$$R_{eqv}(\omega) = (R_1+R_2)\cdot\frac{\left[1+(\omega/\omega_{3R})^2\right]}{\left[1+(\omega/\omega_1)^2\right]\left[1+(\omega/\omega_2)^2\right]}, \quad (2)$$

Where

$$\omega_1 = G_1/C_1 \quad \omega_2 = G_2/C_2 \quad (3)$$

$$\omega_{3R} = \sqrt{\frac{G_1G_2(G_1+G_2)}{C_1^2G_2+C_2^2G_1}}. \quad (4)$$

The values of the kink frequencies ω1 and ω_2 of the curve of the frequency dependence of the equivalent resistance coincide with the similar values of the kink frequencies of the curve of the frequency dependence of the equivalent capacitance.

It is easy to show that at high frequencies ω/ω1, ω/ω_2, $\omega/\omega_{3R}>1$ expression (2) can be represented as

$$R_{eqv}(\omega) \cong \frac{\left(G_1C_2^2+G_2C_1^2\right)}{C_1^2C_2^2}\cdot\frac{1}{\omega^2}, \quad (5)$$

and at low frequencies ω/ω^1, ω/ω^2, $\omega/\omega_{3R}<1$ in the form

$$R_{eqv}(\omega) = R_1 + R_2. \quad (6)$$

Consider the frequency dependence of the equivalent resistance for a particular case of the ratio of capacitances and resistances of the volume and contact, when $C_2 >> C_1$, $R_2>R_1$. Where in

$$\omega_{3R} = \omega_2\sqrt{1+G_1/G_2} \quad (7)$$

Comparison of relations (3) and (7) shows that ω3R >> ω_2, ω_{3C}. Under the specified condition for the frequency dependence of the equivalent resistance at high frequencies, as well as in the frequency ranges $\omega_2 < \omega < \omega_{3R}$ and $\omega_{3R} < \omega<\omega_1$ from expressions (5) and (2), we obtain, respectively

$$R_{eqv}(\omega) \cong \frac{G_1}{C_1^2}\cdot\frac{1}{\omega^2} = \left(\frac{\omega_1}{\omega}\right)^2 R_1, \quad (8)$$

$$R_{eqv}(\omega) \cong \left(\frac{\omega_2}{\omega}\right)^2 (R_1+R_2), \quad (9)$$

$$R_{eqv} \cong R_1. \quad (10)$$

Let's consider another important particular case, when $C_1>>C_2$, $R_1>R_2$. Wherein

$$\omega_{3R} \cong \omega_1\sqrt{1+G_2/G_1}. \quad (11)$$

From relation (11) it follows that $\omega_{3R} > \omega_1$. In this case, for the equivalent resistance at high frequencies and in the frequency ranges

$\omega_{3R} < \omega < \omega_2$, $\omega_1 < \omega < \omega_{3R}$

we obtain, respectively

$$R_{eqv}(\omega) \cong \frac{G_2}{C_2^2}\cdot\frac{1}{\omega^2} = \left(\frac{\omega_2}{\omega}\right)^2 R_2, \quad (12)$$

$$R_{eqv}(\omega) \cong \left(\frac{\omega_1}{\omega_{3R}}\right)^2\cdot(R_1+R_2) = R_2, \quad (13)$$

$$R_{eqv}(\omega) \cong \left(\frac{\omega_1}{\omega}\right)^2 (R_1+R_2). \quad (14)$$

Thus, it follows from the consideration that the curve approximating the dependence of the equivalent resistance Reqv(ω) of a series equivalent circuit on frequency is described by relations (2)-(14) and on a double logarithmic scale is a broken straight line with three breaks.

Figure 1 shows the real theoretical (1) and approximating (2) curves of the dependence of the equivalent resistance of a series equivalent circuit on frequency, plotted in the coordinates lg Reqv – lgf, where f=ω/2π, according to the obtained relations for the structure with C_1=1700 pF, C_2=150 pF, R_1=5·105 Ohm, R_2=5·104 Ohm.

It can be seen that the approximating curve 2 agrees with the real one. The approximation error is maximum at the break points of the characteristic and is about 50%. The same agreement was observed with the results of [1,4]. For comparison, the same figure shows an approximating curve 3 corresponding to a simplified series equivalent circuit [5], in which the contact resistance is not taken into account. Comparison of curves 2 and 3 shows that the influence of the contact resistance on the curve of the frequency dependence of the equivalent resistance is manifested by the presence of additional breaks at frequencies ω1 and ω3R and a rise in the frequency range ω1 < ω < ω_{3R}.

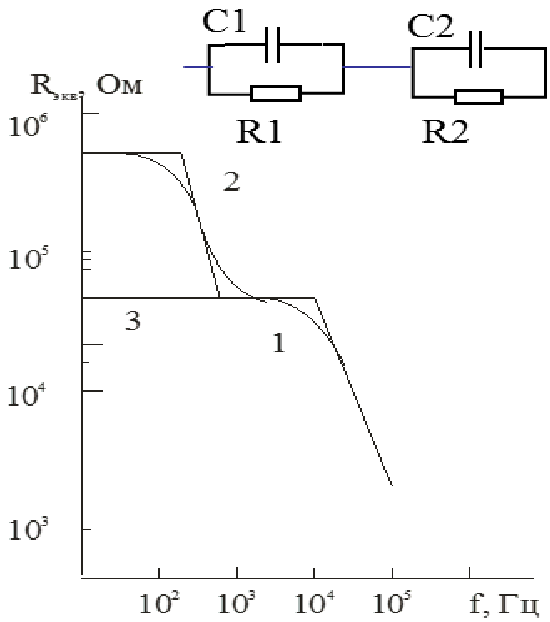

Fig.1. Real (1) and approximating (2, 3) curves of the dependence of the equivalent resistance on the frequency.

3. Conclusion

Thus, an approximation of the frequency dependence of the equivalent resistance of a series equivalent circuit of Schottky metal-semiconductor contacts is proposed, taking into account the resistance and capacitance of the contact and volume in the form of a broken line with several breaks. The performed analysis showed that the shape of the curves of the frequency dependence of the equivalent resistance does not depend on the ratio of capacitances and resistances of the contact and volume, only the values of the break frequencies change. So, at C_1>>C_2, R_1>R_2, the frequency ω1 is the smallest, and ω_2 is the highest break frequency. At C_2>>C_1, R_2>R_1 the reverse situation takes place. The break frequency ω_{3C} in both cases is between the frequencies ω_1 and ω_2.

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Energy saving system in vacuum unit

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Abstarct: In order to save energy consumption in the vacuum section, I was studied as a technological process control object. Instead of two ejectors to create a vacuum in the main purpose K-10 tank, one vacuum hydrocirculation device was replaced with a modern vacuum creation system. As a result, energy was saved in the vacuum technological process.

Keywords: Vacuum boiler, Energy saving, Control system, Fraction, Technological process, Hydrocirculation device.

1.Introduction

In the vacuum section, the heavy product, fuel oil, obtained from the expulsion of oil in the atmospheric block is supposed to be expelled under vacuum. The products received in the vacuum section are used as raw materials for the catalytic cracking unit, vacuum gas oil and as raw materials for the coking unit. The main component of boiler fuel is tar as a finished product. The technological scheme of the vacuum unit is depicted in Figure 1. Technological devices used in the vacuum unit: K-2 lower part of the rectification coil, K-10 vacuum coil, S-3 tube furnace, K-11 evaporator coil, T-12 buffer tank, Ej-1 and Ej-2 steam ejectors, Id -4 and Id-5 barometric heat exchangers, vacuum generator system separator, Id-1÷Id-3, Id-3a, Id-7, Id-10 heat exchangers, HS-9, HS-36÷HS-38, HS-40 air coolers, SS-36, SS-39 water coolers, N-1, N-2, N-21, N Includes pumps -24÷N-27. The residual product of the atmospheric boiler is taken from the bottom of the fuel oil K-2 rectification boiler at a temperature of 360oS÷390oS through pumps N-21/1,2,3 and transferred to the serpentine tubes of the furnace S-3 in four streams. In order to heat the fuel oil to the required temperature in the S-3 furnace, 24÷30 tubes are provided in its radiation zone and 74 tubes in the convection zone. Fuel oil is successively heated to a temperature of 390oS÷430oS in the S-3 furnace, passing through the radiation and convection tubes, four streams are combined into one stream, and transferred to the feed line of the K-10 boiler. Distillates are separated in a vacuum flask. K-10 is an apparatus with a height of 33.6 m and a diameter of 9m.

Due to the depth of the vacuum created inside the boiler, the number of stages in steam ejectors is assumed to be two. 2- and 3-stage steam ejectors are used in oil refineries. In the vacuum block selected as the control object, a two-stage and two-flow heat exchanger in the upper part of the K-10 cylinder simultaneously supplies high and medium pressure water vapor to the Ej-1, Ej-2 ejectors, creating a residual pressure of 60 mm Hg. In addition to ejectors, vacuum generating technological devices include separators, vacuum pumps and barometric heat exchangers. Vacuum pumps are used to suck gases. It is divided into two parts: dry and wet, rotor and piston. Dry pumps are used to absorb dry gases, and wet pumps are used to pump liquid and gas mixtures. Rotor vacuum pumps are equipped with an impeller mounted on non-moving blades. The pump is filled with water and other liquids to the required level. It is necessary to adjust the level of the liquid in such a way that when the pump is running, the paddles remain in the liquid. The depth of the vacuum obtained in the pumps depends very much on the working temperature of the pumped liquid. Pumps with productivity - 720÷1800 m^3/h - 720 mm mercury column are for creating vacuum. Productivity - 160÷200 m^3/min variable piston dry vacuum pumps can create a pressure of 30 mm Hg column. Inside the barometric heat exchanger there are special partitions and containers with a conical cylindrical bottom. Hydrocarbons, decomposition gases, water vapor and air separated from the upper part of the vacuum tube are supplied to the lower part of the barometric heat exchanger. Cold water is injected into the upper part.

The rising vapors collide with the falling water and condense. The remaining products are absorbed by means of a vacuum pump and steam ejectors.

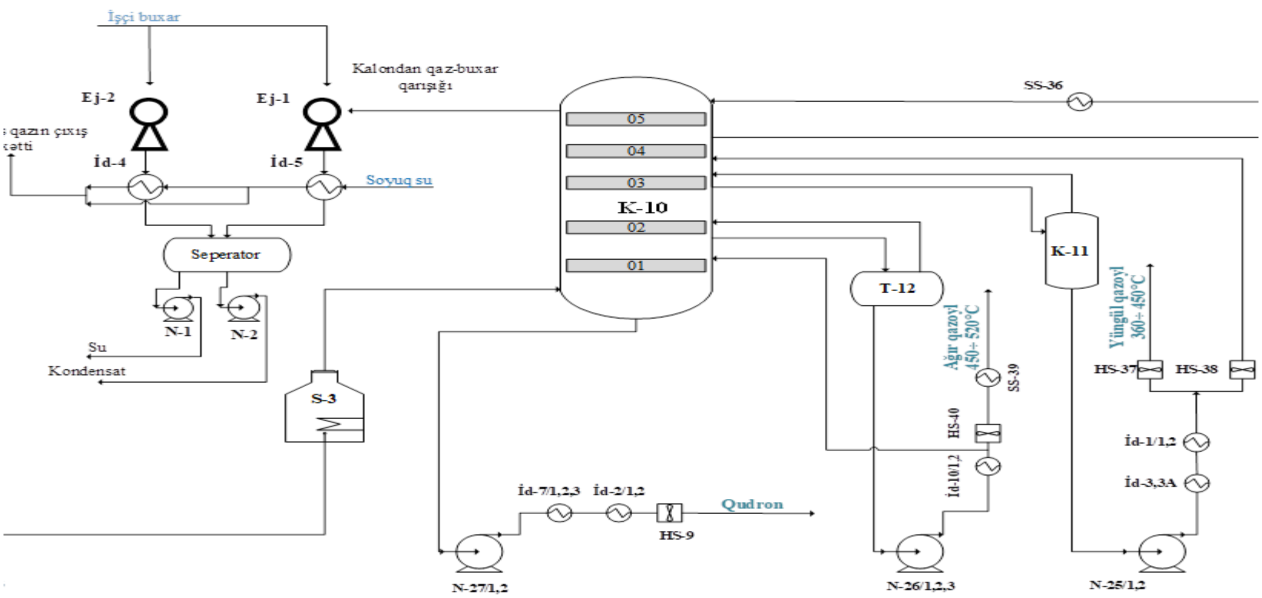

Figure. 1. Technological scheme of the vacuum block

The structure of the barometric condenser should be such that the temperature of the water leaving it is equal to the temperature of the entering steam, and the temperature of the air leaving its upper part is equal to the temperature of the entering water. Oil vapors are taken from the upper part of the K-10 cylinder. The tar obtained from the lower part of the boiler passes through the heat exchangers at a temperature of 3600S÷3700S, is cooled to 900S÷1000S, and is sent to the commodity park. Modern materials science has invaluable services in the field of energy [1-9].

2. Experimental details

In the primary oil processing facilities, in the vacuum section of the ELOU-AVT-6 unit, two Ej-1 and Ej-2 steam ejectors with a two-stage and two-flow heat exchanger are created in the K-10 vacuum cylinder. However, this system can be replaced by an energy-saving and environmentally friendly vacuum generation system. The considered system used to create a vacuum in the petroleum, petrochemical and chemical industries can be replaced by traditional vacuum creating systems. Certain recommendations have been made regarding the modern vacuum generation system, which competes with traditional systems and has certain advantages when compared with them [10÷14]. The main areas of the hydrocirculated modern vacuum creation system: - vacuum distillation of oil fractions; - vacuum distillation in various petrochemical and chemical technological processes; - kalons used during drying of diesel fractions; - creating a vacuum in the steam-turbine condenser; - creating a vacuum in dryers, desorbers, desalinizers, evaporators and other equipment. With the help of a modern system vacuum hydrocirculation unit, a 25 mm Hg column pressure is obtained in the upper part of the K-10 vacuum cylinder. Meanwhile, 2000 kg/h gas-steam mixture is sucked from the vacuum cylinder. The working life of this system is 8000 hours. Working liquid diesel fuel and 360oS÷450oS fractions are used in certain units. The considered system does not need working steam, so it saves energy, eliminates product losses, is easy to use and very reliable. The fission gases can be compressed to a pressure of 0.105 MPa and transferred to the furnace for burning [15÷17]. The following equipment is used in the vacuum creation system: - V-1 vacuum generator, - Sp-1 separator, - N-1/1,2,3 pumps, - SS-1v and SS-2v water coolers. From the top of the K-10 vacuum cylinder, hydrocarbon vapors and fission gases are transferred to the V-1 vacuum generating structure at a pressure of 25 mm Hg as a passive working body. In such structures, the active working body is the fraction of 360oS÷450oS pumped with N-1/1,2,3 pumps at a pressure of 5.9 MPa. During this process, compression of hydrocarbon decomposition gases and condensation of vapors is obtained under a pressure of 0.105÷0.11 MPa. The resulting gas-liquid mixtures enter the Sp-1 separator and are separated into gas and liquid phases. From the lower part of the separator, the liquid phase is transferred to the SS-1v and SS-2v coolers, where it is cooled to a certain temperature with water and then transferred to the N-1/1,2,3 pumps. Fresh 360oS÷4500S fraction is transferred to the Sp-1 separator in the amount of 175 m3/h in order to feed the closed circuit of the working liquid in the system and to update it [18-20]. Figure 2 shows a modern vacuum creation system based on hydrocirculation devices.

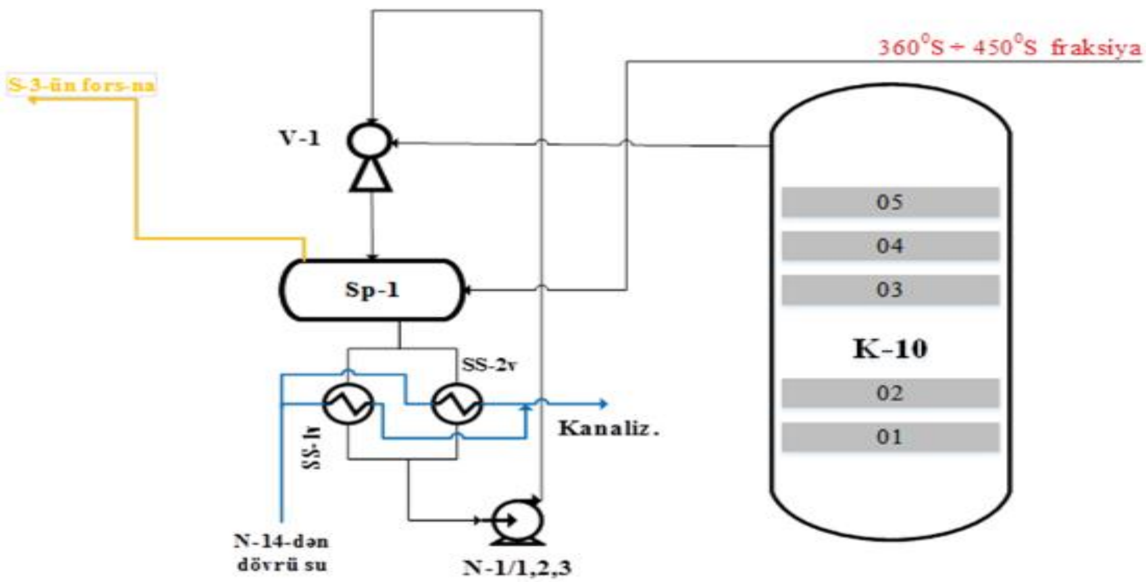

Figure 2. Modern vacuum creation system based on hydrocirculation devices

Table 1. Energy consumption in a comparative way

Communal values	Units of measure	Through steam ejectors Ej-1 and Ej-2	Based on vacuum hydrocirculation devices
Working steam consumption	Tone	0.05167	0.0283
Cooling water consumption	m^3/ton	12.69	10.5
Power consumption	kW·h/ton	2037	1000

3. Conclusions

A modern vacuum generation system based on a hydrocirculation unit has the following advantages compared to steam ejectors: - energy saving due to reduction of steam and cooling water consumption, - due to reduction of product losses with exhaust steam condensate, - improvement of environmental safety in enterprises due to reduction of heat emission and reduction of contaminated steam condensate. The application of a modern vacuum system based on hydrocirculation devices in the control facility results in a reduction of wastewater treatment costs, savings in utility services, and an increase in the productivity of vacuum distillates due to stabilization of the pressure in the upper part of the K-10 vacuum cylinder. The replacement of Ej-1 and Ej-2 steam ejectors with a modern vacuum generation system based on vacuum hydrocirculation devices significantly reduces the energy consumption of the entire vacuum unit.

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Modernization of the goals and objectives of teaching the course of mathematics in a technical university

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Abstract: The main objectives of the discipline "Higher Mathematics" are: mastering the methods of linear algebra, vector algebra and analytical geometry, differential and integral calculus, the apparatus of differential equations, numerical and functional series, multiple integrals, field theory, probability theory, mathematical statistics. The knowledge acquired in the study of this discipline will allow the future specialist to solve actual problems of practice in his daily activities, understand the results of other studies obtained at the modern scientific level and thereby improve his professional skills. This discipline is a continuation and deepening of the study of mathematics, begun at school, and is the most important basis for studying the disciplines of specialization.

Keywords: Mathematecis, Integrals, Field theory, Modern scientific.

1.Introduction

In the modern period of the development of society, characterized by fundamental changes in the socio-economic, political and other spheres, the goal of higher education is the formation of creatively thinking high-level specialists, which requires creative abilities, cooperation between teachers and students in the educational process.

The need to develop new approaches to education is dictated by society's dissatisfaction with its quality. Changing the conditions of society inevitably leads to the improvement of educational concepts. The current stage of development of education is characterized by qualitative changes in its content, structure, the introduction of new pedagogical technologies into the educational process. At the same time, an important role in reforming education is assigned to the developing process of informatization, which allows the widespread use of information technologies [1,3].

Informatization of education is the process of providing the education sector with methodology and practice for the development and optimal use of modern information technologies, or, as they are commonly called, new information technologies. This process initiates, firstly, the improvement of the mechanisms for managing the education system based on the use of automated data banks of scientific and pedagogical materials, as well as communication networks, and secondly, the creation of methodological training systems focused on the development of the intellectual potential of the student, on the formation of skills to independently acquire knowledge, to carry out various types of information processing activities, thirdly, the creation and use of computer training, testing, diagnostic methods for acquiring, monitoring and evaluating the level of knowledge of students. The problems of informatization of education should be reflected in promising pedagogical programs, scientific research in the field of computerization of primary, secondary and higher education [2, 4].

The emergence of new information technologies, their rapid improvement and dissemination, led to the realization of new educational tasks such as informatization of education, computer literacy and information culture.

Formulation of the problem. The proposed article analyzes the modernization of the goals and objectives of teaching the course of higher mathematics at a technical university in the context of informatization of mathematical education, namely:

- between the social order of society for highly qualified specialists and the insufficient level of information culture of graduates of technical universities;
- between the traditional methodology and technology of education and modern requirements for the level of knowledge, integrative skills, information culture of specialists (engineers, technologists);

- between the potential variety of new forms of student education and the continuation of their education according to the traditional method.

In accordance with the state educational standard, the goals of studying the discipline "Higher Mathematics" in a technical university are as follows [3]:

a) educating students of a high mathematical culture (sufficient for the application of the mathematical apparatus in their future professional activities);

b) instilling the skills of modern types of mathematical thinking;

c) instilling skills in the use of mathematical methods and the basics of mathematical modeling in practical activities.

These goals are achieved on the basis of:

- familiarization of students with the role of mathematics in modern life, with the characteristic features of the mathematical method of studying real problems;
- teaching students the basic theoretical provisions necessary for the study of general scientific and special disciplines;
- development of students' skills of creative and logical thinking;
- education of mathematical culture, the necessary intuition and erudition in matters of applications of mathematics;
- developing skills to bring the solution of the problem to a practically acceptable result - numbers, graphics, accurate qualitative conclusion, etc. with the use of adequate computing tools, tables and directories for this;
- developing the ability to independently understand the mathematical apparatus used in the literature related to the specialty.

Method of teaching. The main objectives of the discipline "Higher Mathematics" are: mastering the methods of linear algebra, vector algebra and analytical geometry, differential and integral calculus, the apparatus of differential equations, numerical and functional series, multiple integrals, field theory, probability theory, mathematical statistics. The knowledge acquired in the study of this discipline will allow the future specialist to solve actual problems of practice in his daily activities, understand the results of other studies obtained at the modern scientific level and thereby improve his professional skills. This discipline is a continuation and deepening of the study of mathematics, begun at school, and is the most important basis for studying the disciplines of specialization.

The study of higher mathematics provides for lectures, practical classes and independent work of students. The lectures outline the content of the topics of the program, taking into account the requirements established for a specialist in a qualification profile. Practical classes are held in study groups with the aim of consolidating the theoretical foundations set forth in the lecture course, obtaining practical skills in applying theory to solving mathematical problems. Both lectures and practical classes are held in accordance with the plan for the distribution of study time.

Due to the fact that at present the use of computer algebra systems and computer mathematical systems in universities is becoming real, a new look is needed at setting goals and objectives for teaching higher mathematics in a technical university. Due to the great importance of the applied side of the application of the mathematical apparatus in the professional activities of future engineers, builders, economists, the following should be added to the goals of teaching higher mathematics:

a) formation of skills for automating mathematical calculations (numerical, symbolic, graphical) with the help of computer mathematical systems (including using the programming languages contained in these systems);

b) formation of skills for constructing mathematical models of technical processes suitable for implementation in computer mathematical environments [1].

One of the important issues in the development of science and education is the application of grapheme-based materials in the preparation of intellectual boards [7-19].

2. Experimental details

The setting of these goals will also determine the modification of the tasks of teaching a course of higher mathematics in a technical university: teaching students the method of linear algebra, vector algebra and analytical geometry, differential and integral calculus, the apparatus of differential equations, numerical and functional series, multiple integrals, field theory , probability theory, mathematical statistics to be carried out in close connection with the development of computer mathematical systems by students on the basis of the integrated use of these systems in the educational process.

The main thing in teaching mathematics and mathematical methods to students of a technical university is to teach students how to learn, to develop in them a deep need for mathematical knowledge, a desire to improve and update knowledge, and the ability to apply them in practical activities. One of the conditions for the effectiveness of the educational process is the presence of interest in the subject being studied.

Of particular importance is the use of new information technologies in such a type of educational activity of students as independent work. Independent work of students is a form of organization of their educational activities, carried out under the guidance of a teacher, during which students independently perform various types of tasks in order to acquire knowledge, develop skills, abilities and personal qualities. Information technologies make it possible to construct new methodological forms of presentation of educational material and new forms of management and control over students' independent work.

In order to overcome the gap between the level of mathematical knowledge of university graduates and the needs of modern science and technology, it is necessary, in our opinion, to do the following.

- To radically revise the content of the mathematics course, significantly reducing technical issues and getting rid of the routine; exclude or reduce sections that duplicate the school curriculum; include the most important sections of modern mathematics, paying more attention to solving synthesis problems, and the plans for lectures and practical exercises should be developed taking into account computer support, which will free up the time necessary for new sections.
- Move the emphasis in the triad ``what-how-why' from the question ``how' (to solve, calculate, etc.) to the questions ``what' and ``why'", in many cases leaving the solution of the question ``how "professional mathematicians and computers, and the problem of `` what does a person do and what does a computer do' is the subject of a special study and needs methodological justification in each specific case.
- Prepare and implement educational complexes and workbooks for students, use paperless technologies (for example, accepting homework, standard calculations, tests in the form of files, the verification of which will be entrusted to a computer), develop teaching aids (printed and electronic) containing detailed recommendations for each lesson, taking into account computer support, to introduce modern forms of studying mathematics.
- Equip computer labs for classroom activities, test activities and student self-study and distribute the software for these classes so that students and teachers can have it on home computers. Aim the policy of mathematical departments to promote mathematics to senior courses, develop and offer new mathematical courses, including those of a humanitarian nature (for example, on the history and methodology of mathematics), introduce various forms of independent work of students (including coursework work in mathematics)
- Prepare a variety of mathematical courses to improve the skills of engineers, researchers and teachers, including distance learning.

3. Conclusions

Summarizing our proposals for overcoming negative trends in mathematics education, we highlight the main directions for their practical implementation:

Modernize the course of mathematics, freeing it from routine and shifting the emphasis from the question "how" (solve, calculate, etc.) to the questions "what" and "why". Use the free time to discuss and study the results obtained, as well as to include new sections of modern mathematics in the program; create a unified educational and scientific information environment that allows you to effectively use computers for classroom lessons, control activities and, especially, for independent work of students in full-time and distance learning; develop and introduce a new type of educational literature both on traditional paper and electronic media (educational complexes, electronic textbooks and teaching aids, workbooks for students), as well as control and training computer packages; equip computer classes with appropriate software and methodological support for conducting classroom classes, control activities and independent work of students; develop special software tools, converters and other software products that allow teachers to more effectively engage in scientific work, create teaching aids (printed and electronic) and prepare articles and books for publication at a high typographical level.

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Development perspectives of agriculture of the southern region

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Abstract: Although there are different types of rice, the most widespread in the region are "Agh-anbarbu", "Kirmyzi-anbarbu", "Sadri", "Hasani", "Hashimi", "Yetimi", "Champoo", "Akula". the places are Lankaran and Astara regions.In order to expand rice fields in Lankaran, scientific works are being carried out at rice stations in the region. In Azerbaijan, rice cultivation is carried out in the Sheki-Zagatala and Guba-Khachmaz regions, in addition to the Lankaran-Astara economic region. After cereals, citrus fruits are the most widely planted on soils suitable for cultivation. The agricultural potential of citrus fruits, which occupy a very important place in Lankaran region, is very high. Subtropical fruits such as tangerines, oranges, lemons, grapefruits, feijoa, kiwi are grown here. The region also has subtropical plants of eucalyptus and bamboo. In the region, citrus groves were planted mainly in Lankaran and Astara regions. More than 5,000 hectares of citrus groves have been planted in these two regions.

Keywords: Regions, Lankaran, Subtropical, Cereals.

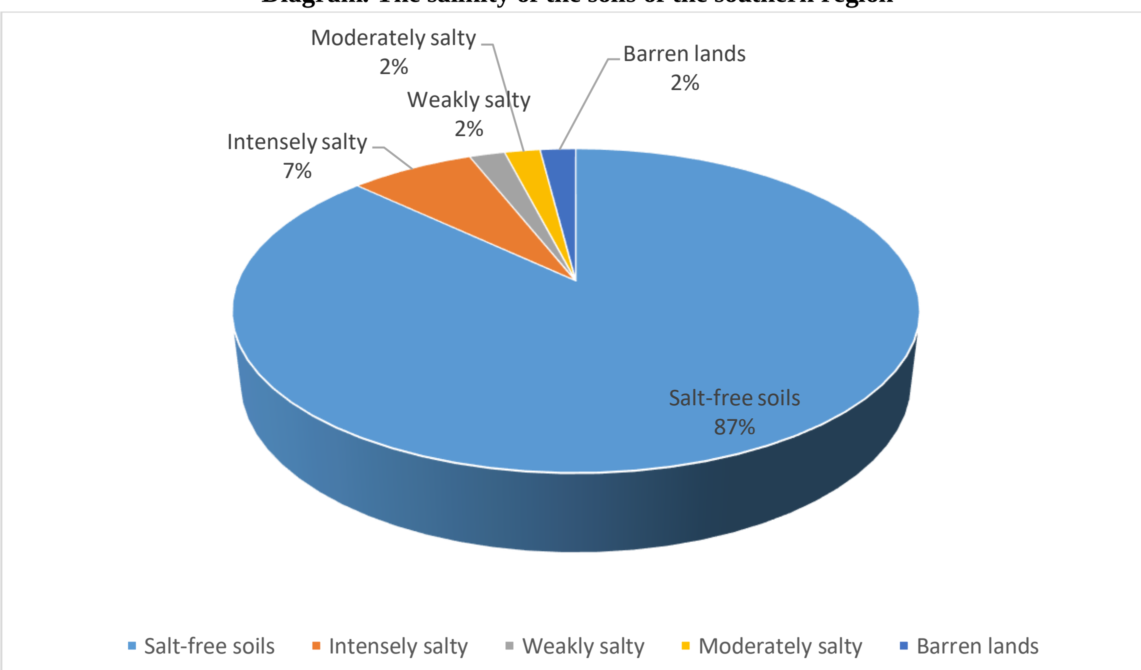
1.Introduction

The southern region is the region of Azerbaijan with the highest agricultural potential due to its climate and soil characteristics. However, the region has not reached the desired level in the production of agricultural products. Management of agricultural land requires a new land reform. With the collapse of the USSR, the privatization of only 15.21% of agricultural land clearly shows the need for land reform in the region. As in the whole of Azerbaijan, the lands in the southern region are divided into three parts. 57.14% of the lands are state owned, 19.22% are municipal, and 23.64% are privately owned. The rivers of Lankaran region occupy a very important place in agricultural work. The Khanbulanachay reservoir was built for the purpose of irrigation. 66 million m3 of water from this dam is used in agriculture every year. Taking into account the climate and precipitation regime of the research area, the importance of irrigation in increasing productivity in agriculture is great. In the dry summer season, irrigation water needed for agricultural products is provided in the region with small volume dams built on Besharuchay, Lankaranchay, Veravulchay, Lekarchay, Khan-bulanchay and Boladichay rivers. One of the most important problems of agricultural productivity in the region is soil salinization. Every soil has more or less salt. As salt accumulates in the soil, the soil becomes unsuitable for agriculture. For this reason, the method of irrigation in agricultural activities should be done consciously. In irrigation with traditional irrigation methods, the salt in the soil accumulates on the surface of the soil by evaporation. Sprinkler and drip irrigation prevents salinization and increases agricultural productivity so that the soil does not lose its arable character. The area with more salinized soils is Jalilabad region with 79.71% (table 1). Due to the drought in Jalilabad region, the abundance of land in need of irrigation has increased the salinity here. Then 18.15% Masalli district and 2.14% Lankaran district are other districts with salinization problem [2].

Table 1. Salinity status of the soils of the southern region

Cities	Land suitable for cultivation (Hectare)	Without salt (Hectare)	Weakly saline (Ha)	Moderately salty (Hectare)	Excessively saline (Hectares)	Barren land (Hectares)	Total of saline soils (Hectare)	Distribution by regions %
Masalli	33112	29573	2192	534	813	-	3539	18.15
Celilabad	96535	80989	1250	1924	9816	2556	15546	79.71
Lenkeran	24066	23648	172	246	-	-	418	2.14
Total	153713	134210	3614	2704	10629	2556	19503	100 %

Diagram. The salinity of the soils of the southern region



2.Experimental details

Most of the arable land of the southern region is used for grain cultivation. Grain cultivation in Lankaran region shows continuous development in parallel with the increase in the population. Since the demand for wheat, which is the main source of food for the people, is high, priority is given to wheat in grain cultivation, and wheat is in the first place in grain cultivation with 81% share. In addition to wheat, the most important grains in the region are rice and barley. In terms of grain production, Jalilabad region's production exceeds the total output of all other regions. The summer dry desert climate of the region has led Jalilabad region to be in the first place in terms of grain production with 77% of the total output. After Jalilabad district, Masalli district has a large share in grain production. Thus, in 2021, 26915 tons of grain were produced in Masalli district. There is a steady increase in grain production. Production increased from 186,171 tons in 2005 to 264,135 tons in 2016. It remained at the level of 239,573 tons in 2021 (table 2). [1]

Table 2. Grain production in the southern region by year (tons)

Regions	2016	2017	2018	2019	2020	2021
Astara	2989	4023	3850	2962	2702	2778
Calilabad	216009	194602	179847	240697	179294	186095
Lerik	4236	6663	6794	7079	7061	7276
Lankaran	2921	3851	5589	5934	5919	8135
Masallı	30428	20533	26263	25961	24841	26915
Yardımlı	7552	8302	8525	8723	8801	8374
Total	264135	237974	230868	291356	228618	239573

One of the oldest agricultural fields in the Lankaran-Astara economic region, rice cultivation is a highly productive and profitable product. Rice cultivation suitable for the climate of the region is carried out in low and wet areas. It takes 30-32 days from full germination of rice to tillering. The period from the end of bushing to the end of flowering is 22-25 days. Rice ripens in 115-135 days. Rice is not used directly in the food industry. Rice is obtained as a result of polishing rice in the processing process. When rice is processed, 65-75% rice is obtained, depending on the applied processing technology. [3] Rice farming creates natural conditions for waterfowl. It contributes positively to the development of freshwater fisheries and animal husbandry. Rice fields are popularly called "Bijar" which is made up of the words birz-rice and car-suluyer. Although there are different types of rice, the most widespread in the region are "Agh-anbarbu", "Kirmyzi-anbarbu", "Sadri", "Hasani", "Hashimi", "Yetimi", "Champoo", "Akula". the places are Lankaran and Astara regions.In order to expand rice fields in Lankaran, scientific works are being carried out at rice stations in the region. In Azerbaijan, rice cultivation is carried out in the Sheki-Zagatala and Guba-Khachmaz regions, in addition to the Lankaran-Astara economic region. After cereals, citrus fruits are the most widely planted on soils suitable for cultivation. The agricultural potential of citrus fruits, which occupy a very important place in Lankaran region, is very high. Subtropical fruits such as tangerines, oranges, lemons, grapefruits, feijoa, kiwi are grown here. The region also has subtropical plants of eucalyptus and bamboo. In the region, citrus groves were planted mainly in Lankaran and Astara regions. More than 5,000 hectares of citrus groves have been planted in these two regions.

In 2021, 55,559 tons of fruit were harvested from citrus orchards in Lankaran, Astara and Masalli regions. In the citrus orchards, tangerine was preferred, as a result of which the majority of the obtained product, i.e. 45,767 tons, is accounted for by tangerine. 5275 tons of lemons and 4517 tons of oranges were collected (table 3).

Table 3. Production of citrus fruits in the southern region by year (tons)

Citrus fruits	2016	2017	2018	2019	2020	2021
Lemon	4515	4523	4555	4761	4880	5275
Orange	3003	3017	3090	3477	3926	4517
Tangerine	39152	35221	37016	38537	39923	45767
Total	46670	42761	44661	46775	48729	55559

[1] In the foothill villages, there are natural climatic conditions favorable for the development of this area. High income and increased demand in the production of citrus fruits leads to the expansion of cultivated areas. In recent years, there has been a continuous increase in the production of citrus fruits, the main reason for which is the state program for the development of citrus fruits for 2018-2025. The implementation of the state programs adopted in recent years with the aim of meeting the population's demand for food products, and the measures taken within the framework of the promotion of the production of export-oriented products in the agrarian field have led to the achievement of important results in the development of traditional agricultural fields in the country, especially citrus farming. [4] In Lankaran, which is located in the subtropical zone, along with grain growing and citrus growing, tea growing is considered one of the priority areas of agriculture. There are ample opportunities for the development of tea cultivation here. The tea farms operating in the region skillfully use the possible opportunities and do the necessary work for the development of this area. 94% of cultivated areas and 94.7% of production are in the southern region. In 2017-2021, 985 hectares of new tea plantations were established. Currently, 10 tea processing factories with an annual processing capacity of 24.3 thousand tons are operating in the republic. The area of tea plantations continued to increase every year after the Khanbulanchay reservoirs with a capacity of 52 million cubic meters in the Lankaran district and Vilashchay reservoirs with a capacity of 46 million cubic meters in the Masalli district were put into use. Currently, the area of tea plantations has reached 13.4 thousand hectares, and the production of tea leaves has reached 1121.2 tons. 788.5 tons of it belongs to Astara region, 317.2 tons to Lankaran region, and 15.5 tons to Masalli region (table 4). [1]

Table 4. Tea production in the southern region (tons)

Regions	2016	2017	2018	2019	2020	2021
Astara	645.4	476.7	530.2	583.3	628.0	788.5
Lankaran	313.2	241.0	278.1	281.7	232.0	317.2
Masallı	3.0	3.0	5.3	8.9	15.5	15.5
Total	961.6	720.7	813.6	873.9	875.5	1121.2

At the expense of local production, it can be said that 65-70% of the country's population's need for dry tea is met. The development of citrus farming, paddy cultivation and tea cultivation, which are the main source of income of the southern region, satisfies most of the demand for these products in the domestic market, and also plays a major role in providing employment to the population. Within the framework of the State Program, it is planned to further expand the area of tea plantations in the farm until 2027. The implementation of tea planting here with more Japanese technology has a positive effect on productivity. In addition to the "Yashil Chay" farm, "Astara Chay" LLC, "Beta" LLC, "Ferman Chay" LLC, "Tuado Chay" LLC, "Gilan Orchards" LLC, "Ayna" LLC and Lankaran Tea are specialized as scientific practice bases. we can mention tea farms [5] Tea plantations are irrigated using the sprinkling method. Modern machinery and equipment are brought from abroad for use in the farm. Chemicals are not used during plantation care. Organic fertilizers are used more often instead of mineral fertilizers. As a result, the tea leaves grown here are completely ecologically clean [6-7].

3.Conclusion

During the study of agriculture, it is also important to determine ways to improve its material and technical base. In addition to being one of the main indicators of field intensification, this factor is also important for the cultivation of products, their agrotechnical care, collection and transportation. This factor allows for high productivity of agriculture, crops are cultivated, collected and transported with a small number of workers. Soil salinization is considered an important problem. Pre-saline soils that are not properly irrigated or used properly become saline. This process is called re-salination. In order to use such lands, it is necessary to solve the problem of their salinization. For this, those soils are washed with water and cleaned of salts. One of the main directions of efficient use of land is the protection of areas suitable for agriculture, their use according to their purpose, and the prevention of non-agricultural use. One of the main directions of agricultural development is the creation of specialized production facilities. Already, such farms are established in the fields of grain growing, animal husbandry, and vegetable growing in separate regions of the country, they operate in the form of agroparks. In such farms, high productivity is achieved due to the use of qualified personnel potential, the area of new seed varieties, and the increase in the number of animals. It is possible to organize agroparks in the fields of fruit growing, tobacco growing, cocoon growing, and tea growing in the economic region. They can be organized through the consolidation of existing peasant farms. Agriculture is considered a priority area in the southern region. Diversified development of agriculture is one of the important issues. There are great traditions of tea growing in the region. In order to continue these traditions and meet the domestic demand, new tea plantations should be established on vacant lands that are not used, on lands suitable for tea cultivation. Tea plantations are planted in the foothills and slopes in a terraced manner. This also applies to the production of citrus fruits. It is also possible to develop citrus growing in the foothills by building new fields and increase production. Rice farming is a traditional farm for the southern region. New technologies used in both sowing and harvesting in rice farming play an important role in the development of rice farming. Further strengthening of the measures taken in the direction of the development of rice farming will give impetus to the development of this field.

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Analysis of risk-propendent factors in lemon production in Lankaran district

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Abstarct: The agricultural sector is one of the strategic sectors in terms of the nutrition and employment of the population and the development of countries all over the world. Many risk factors are encountered in agricultural production, which has an important economic and social role. In this article, the factors affecting the behavior of farmers who grow lemons in Lankaran region are studied. For this purpose, a survey was conducted among 270 lemon producers in the study area. It was determined that 45.7% of producers are risk-loving, 28.5% are risk-neutral (indifferent), and 25.8% are risk-averse. Sequential Probit Model was used in the analysis of the obtained data. Factors affecting the behavior of producers in the face of risks encountered in lemon production have been determined. The results of the research can help manufacturers make the right decisions at the right time.

Key words: Lankaran, Lemon, Producer, Risk, Risk propensity, Analysis of risk factors.

1.Introduction

The place of the agricultural sector in the country's economy is measured by the added value created by agriculture in the general economy. Activities in the sector, besides meeting the country's food demand, on the other hand, contribute to the economy by creating employment for a significant part of the population. The agricultural sector has been one of the driving forces of economies from the past to the present day. Agricultural development can stimulate progress in other areas, including industry, through the multiplier effect. In addition, agricultural exports can contribute to capital accumulation by providing foreign exchange inflows. It is known that today's developed countries have made progress in the agricultural sector in the past and started industrialization. Therefore, the agricultural and industrial sectors are closely related to each other. Developed countries that effectively continue industrialization processes are also successful in this field by applying their technological equipment to agricultural fields [1-17]. Today, the significant increase in the cost of agricultural products highlights the problem of ensuring efficiency in agriculture. Producing more products at less cost and competing with other businesses is a very important challenge. The information resources used in agriculture play a very important role in solving such issues. The level of income of agricultural business owners is usually much lower compared to the profitability established in industrial areas. In other words, the fact that the profits of the producers of agricultural products are lower than the producers of the industrial sector is a distinguishing feature of the agrarian sector. In addition, the production cycle of agricultural products is quite long compared to the production cycle in the industrial sector. This does not allow production to be adjusted according to demand[2]. The negative effects of climate factors, changes in the prices of products and input resources, cause fluctuations in the income of producers in Lankaran region. In this regard, the factors influencing the risk attitude of agricultural producers growing lemons in Lankaran region were investigated.

2. Experimental details

A survey method was chosen to determine risk-prone factors in lemon production in Lankaran region. In order to answer questionnaires, farmers were contacted through mutual interviews and by telephone. obtained from questionnaires conducted with the manufacturer. The compilation of data covered the months of February, March, and April 2022. When answering the questionnaires, explanations were given by the researchers regarding questions that were not understood when necessary, the remarks were immediately noted, and necessary adjustments and corrections were made according to these comments. Office Excel' program was used. Query parameters are determined based on the following formula:

$$n=\frac{Nxpx(1-p)}{(N-1)X\delta P^2+PX(1-P)} \quad (3)$$

In the formula:
Measurement of n-sample
Number of farmers engaged in N-production
δp2-ratio dispersion
r: Standard deviation (5%),
Z-scale value (1.645),
p-The number of sample establishments to be included in the survey according to the formula. It is defined as 270 with a 90% confidence interval (z=1.645) and a 5% deviation from the mean.

$$n=\frac{141491\times0.5\times0.5}{141490\times0.00924+0.5\times0.5}\cong 270$$

In the survey, based on pilot sampling groups, 270 people met face-to-face with lemon growers over the course of 3 months. When answering the questionnaires, explanations were given regarding incomprehensible questions, the comments were immediately recorded and necessary adjustments and corrections were made according to these comments. In the evaluation of the questionnaires, 'SPSS' Statistics and Microsoft Office Excel' program was used.

The average age of farmers engaged in lemon cultivation is 49.9, the number of individuals in the family is 4.3, and the number of those engaged in agriculture is 2.0. The average experience of producers in agriculture is 25.0 years, and in lemon production is 22.1 years. The average land assets of the respondents are 8.6 ha, the selling price of lemons is calculated as 0.22 Azn on average. The average lifespan of a lemon tree is 35.0 years, and the transition period of a lemon tree to harvest is 5.2 years.

Table 1. Socio-demographic indicators of the participants*

Variables	Minimum	Maximum	Average	Standard error
Age of Farmers (years)	24	86	55,0	43.84
Number of individuals (people)	1	8	4.5	4.94
Number of individuals working on the farm (people)	1	5	3,0	2.82
Experience on the farm (years)	4	60	25	13.2
Area assets (ha)	1	35	8.6	6.7
Sale price of lemon (AZN)	0.1	0.5	0.22	0.17
Average lifespan of a lemon tree (years)	5	110	35,0	13.5
The transition period of the lemon tree to the harvest	1	11	5.2	2.3

Source: Compiled by authors based on surveys
The family status of the respondents is shown in table-2.

Table 2. Marital status of the participants

Marital status of participants	**Numerically (percentage)**
Married	234 (87%)
Single	36 (13%)
Total	270 (100%)

Source: Compiled by authors based on survey data

Out of 270 people who took part in the survey, 234 people were married and 36 people were single. The analysis of the situation of the farmers in the face of the risk that they may face is shown in table 3.

Table 3. Farmers' risk situations

Risk situations	Number	With interest
A risk taker	88	32.5
Risk averse	99	36.6
Neutral	83	30.9
Total	270	100

Source: Compiled by the authors based on survey statistics

32.5% of the participants said that they are prepared for all possible risk situations, 36.6% do not like risk, and 30.9% said that they can be neutral about possible risk situations.

Table 4. Indicators of lemon producers

Irrigation form of lemon trees		Sales form of lemon		Determining the time of lemon harvesting	
Drip	73	Wholesale	251	I define myself	213
Irrigation with water hoses	185	Retail	13	I ask other farmers	42
other	12	other	6	From the time when the lemon was sold in the market	15

Source: Compiled by the authors based on the statistical data of the survey

27% of the participants use drip irrigation, 68% use water hoses on their farm, and 5% use other methods for watering their lemon trees. 92% - wholesale lemons, 5% - retail, and 3% - other methods. 78% determine the time of lemon ripening by themselves, 15% consult with other farmers, and 7% sonar their crop after the lemon is on the market. 21.5% of lemon producers have non-agricultural investments and 60.5% play games of chance while 18% do not play games of chance. The Sequential Probit model was used to determine the factors affecting the attitude of the producers participating in the survey to risk. The dependent variable in the model is the risk attitude of the producers: Y=0 (risk averse), Y=1 (risk neutral (indifference)) and Y=2 (analyzed as risk-loving) [4].
Note: : *** indicates significance at 1%, ** 5%, * 10% level.
*** indicates significance at 1%, ** 5%, * 10% level.

Table 5. Marginal effects of risk factors affecting lemon production

Variables	Y=0	Y=1	Y=2
Age (<50=0, 50+=1)	-0.1435**	0.0143	0.1291*
Don't Play a Game of Chance	-0.2797***	0.0119	0.2678***
Agricultural Practices	-0.1776***	0.0106	-0.1776**
Contract manufacturing	-0.1221	-0.0003	0.1670
Budget allocated to Agriculture	0.0951	0.0069	0.0882
Conduct research on lemon production	-0.0667**	0.0071	0.0595**

3. Conclusions

In the study, there is a positive relationship between producers' age and risk attitude and it is statistically significant (P<0.10). In other words, the probability of being in the risk-averse group decreases by 13.25%, while the probability of being in the risk-loving group increases by 11.85% compared to producers aged 50 and older. There is a positive relationship between the level of education of the producers and their risk attitude and it is statistically significant (P<0.05). There is a negative relationship between the producers participating in the study doing any work other than agriculture and their risk attitude and it is statistically significant (P <0.05). There is a positive relationship between the situation of lemon producers who play the game of chance and risk, and it is statistically significant (P<0.01). In other words, the probability of being in the risk-averse group is reduced by 26.93% compared to the others, risk-neutral and and the probability of being in risk-loving groups increases by 1.12% and 25.82%, respectively. There is a positive relationship between the knowledge of good agricultural practices and the risk attitude of the producers participating in the study, and it is statistically significant (P<0.05). In other words, the probability of being in the risk-averse group increases by 16.65% compared to others, while the probability of being in the risk-neutral and risk-loving groups decreases by 1.06% and 17.76%, respectively. One of the most important and easiest measures to minimize risk in agricultural production is agricultural insurance. Especially as the level of education increases, producers resort to this way to ensure their products. Since agriculture depends on natural conditions, risks and uncertainties are inevitable. Even if the latest technology is used, meteorological data should be taken into account, and in this regard, the manufacturers are provided with various TV programs, sms, radio broadcasts, etc. must be informed. Manufacturers should be trained in risk management strategies, risk transfer and risk management, and various seminars should be organized. Research should be conducted to determine the attitudes and behaviors of producers regarding risk. Storage areas should be created, especially for products with high storage risk, such as lemons. In addition, it is important to consider uncertainties in agricultural production such as yield, price and income.

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Investigation of capacitance-frequency characteristics of p-Si/Cd1-xZnxO heterojunctions after sputtering

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Abstract:The electrical properties of p-Si/Cd1-xZnxO heterojunctions obtained by electrochemical deposition were studied depending on the deposition mode, the composition of Cd1-xZnxO thin films and thermal treatment modes in different environments (air, argon and oxygen). The best alignment is observed in heterojunctions based on thin films with x=0.6 and 0.7, which indicates that the difference between their lattice parameters and p-Si is minimal. On the other hand, as mentioned, the dependence of the specific electrical resistance on the composition of the layers in Cd1-xZnxO thin films is non-monotonic.

Keyword: Capacity-frequency dependences, Recombination centers, Electrochemical precipitation methods, Heterojunctions, Electrochemical deposition process, Nanostructure.

1.İntroduction

After heat treatment in oxygen (or argon) environment at 600^0C for 15 minutes, the nature of capacity-frequency dependences changes completely. [3,12] So, as can be seen from Fig. 1, due to the discharge of both levels after TI in the oxygen environment, the height of the descending parts observed in the characteristics also decreases, and the steps are almost not observed in the heterojunctions with x=0.6. It can be concluded from this that the recombination centers formed in thin layers during the technological process and later by the introduction of oxygen to the surface can be controlled, that is, their concentration and activation energy can be controlled by choosing the composition of the layers and the mode of thermal processing.

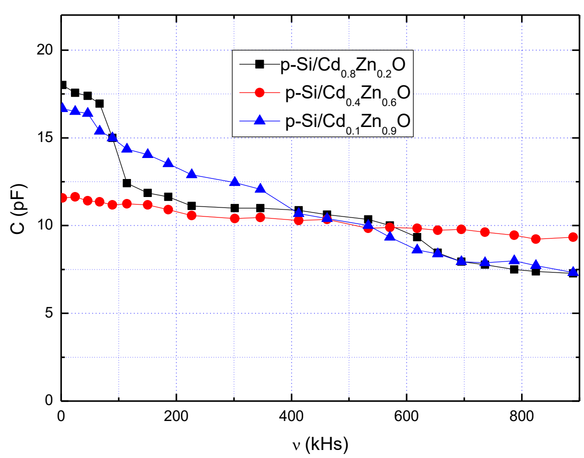

Figure 1. Capacity-frequency characteristics of p-Si/Cd1-xZnxO heterojunctions after heat treatment at 6000C for 15 minutes in oxygen (or argon) environment.

2.Experimental details

The energy depth of recombination centers in the transition region was calculated by means of capacitance-frequency spectroscopy described above. For this, the characteristic frequency of the recombination levels (ν0) was calculated based on the dependence of the switching capacity on the frequency of the external field. Figure 2 shows the graphs $\frac{dC}{d\nu} = f(\nu)$ for different temperatures [1,2,10].

Dependence graphs were constructed based on the characteristic frequencies determined from the graphs and recombination based on the slope of the lines from the graphs. $\ln\left(\frac{\nu}{T^2}\right) = f\left(\frac{1000}{T}\right)$ the energy depth of the levels was calculated (Figure 3). As we mentioned, the observed first step is observed only in heterojunctions with x≠0.6 and is related to the mismatch of the lattice parameters of the materials brought into contact.[5,6,7,8]

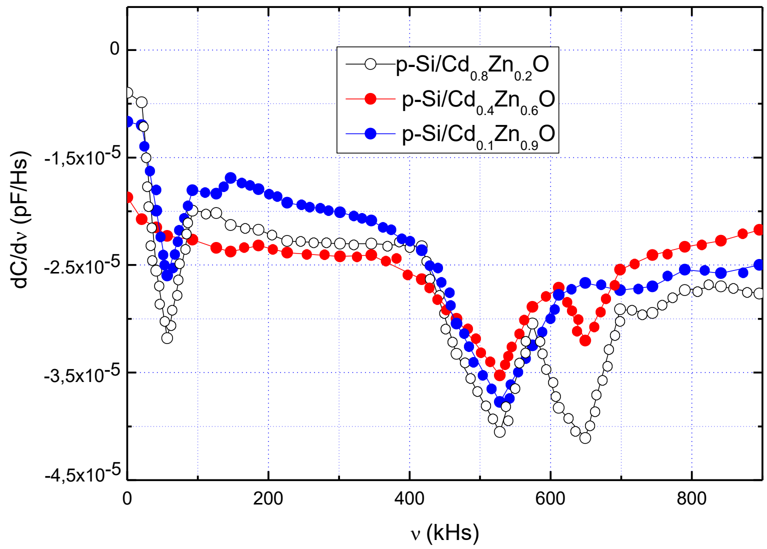

Figure 2. Plots at different temperatures for p-Si/$Cd_{1\text{-}}xZn_xO$ heterojunctions after direct deposition.

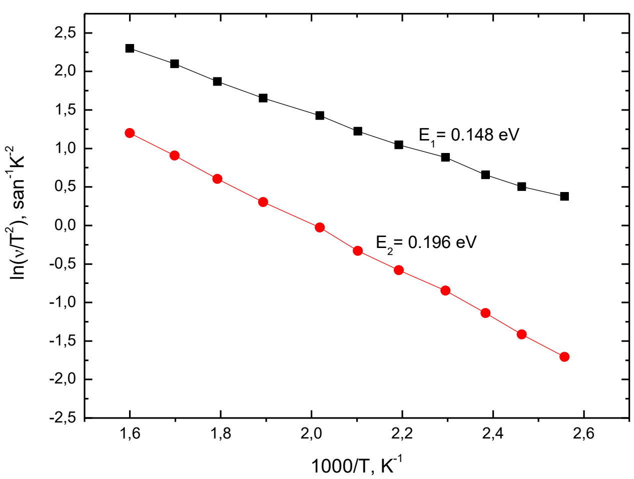

Fig. 2 Graphs of dependence based on characteristic frequencies for p-Si/Cd1-xZnxO heterojunctions.

However, regardless of the composition of $Cd_{1-x}Zn_xO$ thin films, the same value (E_1=0.148 eV and E_1=0.196 eV) is obtained for the activation energy of the second and third type centers in the transition region.[9,10]

3.Conclution

It allows us to say that the first levels are related to the metal hydroxides remaining in the layer during the electrochemical deposition process, and the deeper E_2 acceptor levels are related to the vacancies $[(V_{Cd,Zn}-O)^{+}-(ZnCd_i^{+})]^{++}$ created by oxygen absorbed on the surface after being removed from the reaction solution. All electrical parameters of heterojunctions improve after TP, as both second and third type recombination centers are eliminated by choosing the optimal mode of thermal treatment in oxygen or argon (15 minutes at 6000C). Thus, electrical parameters such as rectification coefficient, non-ideality coefficient of CVA, series resistance can be controlled by thermal processing mode. In heterojunctions with x=0.6,(table 1) the C–2=f(U) law obeys the linear law after TP as well as before TP. At this time, the value of the electrical capacity is relatively small, the values of Vc calculated from CVA and CVF are almost indistinguishable [1-15].

Examples	TP mode	N	Vbi (V)	Vc (V)	Rs (kOm)	K
p-Si/ Cd1-xZnxO	TP mode before	1.74	0.56	0.55	0.07	1640
	200°C, 5 min	1.7	0.56	0.55	0.068	1670
	200°C, 15 min	1.68	0.56	0.56	0.063	1700
	400°C, 15 min	1.45	0.56	0.56	0.055	1950
	600°C, 5 min	1.26	0.56	0.56	0.032	2140
	600°C, 15 min	1.16	0.56	0.56	0.021	2370

It should also be noted that the presence of second levels in most semiconductor thin films of the AIIBVI type has been confirmed in many scientific works and coincides with our results.

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About Integrated monitoring system for ac corona effects of high voltage overhead lines

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Abstract: The issues of the environmental impact of high-voltage transmission lines are becoming relevant in connection with the development of electrical networks of high voltage 110, 220, 330 kV and extra-high voltage (EHV) 500-750 kV and ultra-high voltage 1150 kV. The harmful effect of electric and magnetic fields on living organisms and, first of all, on humans, manifests itself only at very high voltages in the wires of the overhead line (OL) phases, and is dangerous when working under voltage. The direct influence of the electromagnetic field of lines on a person is associated with an effect on the cardiovascular, central nervous systems and other organs. The harmful effects of a person's stay in a strong electric field depend on the strength of the field and on the duration of its exposure. Software has been developed for modeling electromagnetic compatibility, characteristics of power losses to the corona from the voltage impact on the environment. The results of simulation of corona losses are presented on the example of a 500 kV overhead line, electric field voltage and active energy losses due to radio interference.

Keywords: Environmental impact, Overhead power lines, Electric field strength, Corona losses, Radio interference, Acoustic noise, Electromagnetic compatibility.

On high voltage lines 110÷1150 kV, the field strength on the wires during normal operation of the line can reach 25 - 30 kV / sm and more. At a sufficiently high field strength near the surface of the wires, an electrical breakdown of the air occurs. This phenomenon is called corona discharge or corona.

One of the features of extra-high voltage overhead lines is significant power losses to the corona, which in bad weather are commensurate with load losses and therefore, not taking them into account leads to inaccuracy of the mathematical model of the electric power system.

Currently, there are various programs for calculating steady-state conditions and optimizing complex electrical networks. In most of them, corona losses are not taken into account, while others are taken into account either approximately, by introducing power take-offs or active shunts at the ends of transmission lines, or by voltage dependences of corona losses, or by generalized characteristics of corona power losses.

The method of generalized corona losses, obtained experimentally on experimental sites and operating overhead lines, has found wide distribution for calculating average corona losses [8].

The amount of power loss to the corona, caused by local centers of discharge of a space charge moving in the field of the line wires, depends on the amount of space charge and, consequently, on the number and intensity of discharge sources. The theoretical estimation of energy losses caused by the local corona turns out to be impossible due to the difficulties in estimating the number, shape, and size of the discharge sources on the wire surface. Therefore, the current methods for calculating power losses per corona are based on experimental studies of the local corona, on real line wires and on existing power lines.

The least energy losses per line corona occur in good weather (no precipitation on the wires). In rain, sleet, fog, corona losses increase by an order of magnitude. When frost occurs on the wires, the greatest losses are observed, which are even an order of magnitude greater than during rain.

At different times, several empirical and semi-empirical formulas by F. Pick, R. Holm, O. Mayr and others were proposed to calculate corona losses. However, none of these formulas has stood the test of practice, which led to the development of purely experimental work on experimental sections of lines.

A large number of works [1–4] are devoted to methods for calculating corona losses. Corona loss recalculation methods were analyzed in [4], where it is shown that with equal gradients on the surface of two wires with radii r_{01} and r_{02}, and with corona power losses on these wires ΔP_{k1} and ΔP_{k2}, as applied to split wires, the formula has view

$$\frac{\Delta P_{k1}}{\Delta P_{k2}} = \frac{n_1 r_{01}^2}{n_2 r_{02}^2}$$

where n_1 and n_2 are the number of wires.

For the case of a common corona, sufficiently complete similarity criteria are [4]:

$$\frac{\Delta P_{ka} n \varepsilon_0}{\omega C_a^2 U_0^2} = F(\frac{U}{U_0}; \frac{C_0}{2\pi\varepsilon_0}; \frac{r_0 \omega}{k E_0})$$

where r_0 - is the radius of a single wire, n - is the number of component wires in a phase, ε_0 - is the dielectric constant of air, C_f - is the working capacitance of the overhead line phase, ω - is the angular frequency of the voltage, k - is the coefficient of uneven charge distribution over the surface of the component wire.

The ENIN technique [5] is based on the use of a criterion relation of the form

$$\frac{\Delta P_{kf}}{\omega U_0^2 C_f^2 \frac{0.35}{C_e - C_f}} = F(\frac{U}{U_0})$$

To calculate the power losses from the corona of wires of the HVL overhead lines, the current "Guidelines" [6] developed by VNIIE, NIIPT and the ENIN method [5] are currently the most widely used. These techniques are based on experimental data obtained on experimental and industrial lines, and generalization of the corona characteristic to the case of an arbitrary line. In different areas of field strength (local corona, common corona), these techniques have different results. It is believed that the ENIN technique is more accurate in the area of the common crown. The ENIN method gives higher values of losses (except for frost), and at the same time it increases with an increase in the rated voltage.

The average specific power losses for the overhead line corona are calculated for each weather group by summing the phase losses according to the expression

$$\Delta P_{ki} = n r_0^2 (\Delta P_{k1i}^* + \Delta P_{k2i}^* + \Delta P_{k3i}^*)$$

where ΔP^*_{k1i}, ΔP^*_{k2i}, ΔP^*_{k3i} - are, respectively, the values of the generalized corona losses in the phases of a three-phase overhead line for the i-th weather group.

The generalized characteristics of corona losses (4), obtained from the results of long-term measurements for four main weather conditions: fine weather - FW, dry snow - DS, rain - R, frost - F, are given in [6].

The generalized characteristic for rain refers to the average annual rain intensity I=1mm/h. The generalized loss characteristic for any other rain intensity I=1mm/h is determined by multiplying the value ΔP_{kd} by the ratio $k_d = \Delta P_{ki} / \Delta P_{ki=1}$.

The equivalent electric field strength on the surface of the wires is calculated at the operating voltage. The generalized fair weather loss characteristics are given to an air density δ equal to 1.0, and therefore the initial corona strength E_0 in good weather is calculated taking into account the average annual relative air density along the line path.

With the same electric field strengths on the surface of the wires, the power losses to the corona of the mountain overhead line significantly exceed the corresponding flat lines. This is due to the following reasons: lower relative air density in mountainous areas; low value of the coefficient of non-smoothness due to mechanical surface defects caused by wire pulling during installation on stony ground or rocks; no effect of aging of wires due to the special purity of the atmosphere of mountainous areas.

To more accurately take into account the value inside the zone, the line route must be divided into a number of sections by drawing contour lines in height on the route profile. The height between horizontals can be approximately equal to 200-500 m.

The average annual specific power losses per corona for a three-phase overhead line are calculated by summing the losses by phases for each weather group

$$\Delta P_k = n \cdot r_0^2 \cdot (\sum_{i=1}^{4} \cdot \sum_{j=1}^{3} \Delta P_{kij}^* \cdot \psi_i)$$

where ΔP_{kij} - are the values of the generalized corona losses for the i-th weather group of the j-th phase of the overhead line, $\psi_i = T_i/8760$ is the probability of the i-th weather group for the year.

In [6], to take into account the effect of heating by the load current, the concept of critical current density J_{cr} is introduced, which is the lowest current density in the wires of overhead lines, at which, despite the precipitation (hoarfrost, hoarfrost, dew, low-intensity rain, etc.), corona losses do not exceed the level of losses in good weather.

When assessing corona power losses using a simplified method, only four main groups of weather conditions are taken into account and the effect of heating wires by load current on power losses per corona during frost, rain, hoarfrost, dew, high humidity and fog is not taken into account.

Under the influence of heating the wires by the load current, the duration of weather conditions and the amount of losses on the corona during rain and hoarfrost decrease, and deposits on the surface of the wires in the form of hoarfrost and drops of water during fog, high humidity and dew are not formed. The calculated probability of the formation of crystalline frost is determined by multiplying the actual probability based on the observations of weather stations by the correction factor γ_1 [6].

The best approximation to the obtained calculated dependence of the generalized corona loss characteristics for all weather groups is provided by the function [7-8]

$$\Delta P_{ki}^* = a_1 exp[a_2 \left(\frac{E_e}{E_0} - 0.55\right) + a_3 (\frac{E_e}{E_0} - 0.55)^2]$$

The values of the coefficients a_1, a_2, a_3 are given in [7]. The root-mean-square approximation error in this case does not exceed 2%.

The ratio of the average corona loss for rain with a given average annual precipitation rate I to the corona loss for an average annual precipitation rate of 1 mm/h is approximated by the function

$$k_d = 0.0157 \cdot I + 0.96 \cdot I^{\frac{1}{3}}$$

The dependence of the critical rain intensity on the current density J, which takes into account the effect of wire heating by the load current on the corona losses during rain with wire cross sections F=(150-1000) mm^2, is approximated by the function

$$I_{kp} = [0.676 + 0.332 \frac{F}{1000} + 0.632 \left(\frac{F}{1000}\right)^2 \cdot 0.0011 + 0.414 \cdot J + 0.562 \cdot J^2]$$

The generalized corona losses for crystalline frost decrease under the influence of heating by the load current. The critical current density with changes in the wire cross section from 150 to 1000 mm^2 varies within 0.2-0.7 A/mm^2.

The dependence of the correction factor γ_1, which takes into account the probability of formation of crystalline frost under the influence of heating by the load current, is approximated by a function of the form

$$\gamma_1 = (-0.71 + 0.05254 \cdot F)\exp((-2.836 - 0.00875 \cdot F)J)$$

Formula (9) is valid in the range of change $0 \leq \gamma_1 \leq 1$.

The dependence of the correction factor γ_2, which reduces losses during crystalline frost under the influence of heating, is approximated for a wire cross section of 150-600 mm^2 by a function of the form

$$\gamma_2 = 33.42\{exp[-8.41J(0.1726 + 0.2236 \frac{F}{100} - 0.0143 \left(\frac{F}{100}\right)^2)]\}$$

and for sections 600-1000 mm^2 the function of the form

$$\gamma_2 = 33.42\{exp[-8.41J(0.5714 + 0.0243\frac{F}{100} - 0.0078\left(\frac{F}{100}\right)^2)]\}$$

When the influence of heating is taken into account, the generalized losses on the crown for crystalline hoarfrost decrease to the value ΔP^*_{crys}.

The basis for calculating the capacitance of an arbitrary 3-phase overhead line with two cables is the solution of the system of Maxwell equations [6].

2.Experimental details

2.1 Calculation of the electric field strength on the surface of the wires.

The main factor determining corona losses and radio interference on overhead lines is the ratio of the electric field strength on the surface of the wires to the initial corona strength. A small change in this ratio leads to a significant change in corona loss and radio interference.

For an overhead line with a split wire, the electric field strength E on the surface of the wire is determined by the formula [1-4,6]

$$E = \frac{q \cdot 10^{-3}}{2\pi\varepsilon_0 n r_0} kV/sm(10^5\, V/m)$$

where q - is the linear charge density on the wire, K/m; r_0 - is the radius of the components of the split wire, (10^{-2}m); ε_0 - dielectric constant of air.

Maximum tension for split wire

$$E = k_n E \cdot kV/sm(10^5\, V/m)$$

where k_n is the coefficient of non-uniformity of charge distribution over the surface of the component wire.

For a three-phase AC overhead line with single (n=1) and split wires

$$E = 0{,}0147\frac{C_k \cdot U}{n r_0} kV/sm(10^5\, V/m)$$

where $C_к$ is the working capacitance of the k-th phase of the overhead line, pF / m (10^{-12}F / m); U - average operating voltage per year along the overhead line, kV.

When calculating the power losses to the corona on split wires, the equivalent electric field strength $E_э$ is used, which is determined by the formula

$$E = \frac{E + E_M}{2} = \frac{1 + k_n}{2} E\; kV/sm(10^5\, V/m)$$

To unify the calculations for all weather groups, the basic value of the initial field strength E_0 on the surface of the wires was introduced, which corresponds to the appearance of a common corona in good weather conditions and is calculated by the formula

$$E = 24{,}5m\delta\left(1 + \frac{0{,}613}{(r_0\delta)^{0,4}}\right)\; kV/sm(10^5\, V/m)$$

where m - is the coefficient of non-smoothness of the wire; δ - relative air density; r_0 is the radius of the components of the split wire or the radius of a single wire, sm.

Accounting for corona power losses in programs for calculating the modes of electrical networks according to generalized characteristics is complicated, it is simpler to take into account corona losses according to specific characteristics depending on voltage.

2.2 Characteristics of specific corona losses from voltage.

To take into account the corona losses depending on the voltage, in [7] a dependence of the form

$$\Delta P_k = \Delta P_{k0}\left(\frac{U}{U_0}\right)^{\rho}$$

where ΔP_{k0} - specific corona losses at voltage U_0; ρ - exponent.

Accounting for corona losses in the VNIIE program is carried out by introducing fictitious nodes with an active load, simulating corona losses, into the electrical network diagram. The dependence of specific corona losses on voltage is taken into account by a polynomial up to the fourth degree

$$\Delta P_k = a_0 + a_1\left(\frac{U}{U_0}\right) + a_2\left(\frac{U}{U_0}\right)^2 + a_3\left(\frac{U}{U_0}\right)^3 + a_4\left(\frac{U}{U_0}\right)^4$$

where a_0, a_1, a_2, a3, a_4 are the coefficients of the polynomial.

The given technique is implemented in the form of the XARCOR program in the Delphi environment. In the developed complex for calculating capacitance with an arbitrary arrangement of wires, a software module with one and two cables is used.

The block diagram of the integrated system for assessing the impact of the corona wires of the overhead line on the environment is shown in Fig.1.

On fig. 2 shows a screen form of data presentation for an intermediate support in the developed software.

To obtain the characteristics of power losses to the corona, the least squares method - LSM was implemented using the square root method to solve linear algebraic equations. The errors of approximation of the static characteristics of losses to the corona of overhead lines with a voltage of 110-1150 kV with given design parameters were studied. Specifications are based on a voltage range of ±10% U_N.

2.3 Software implementation of corona power loss calculation based on generalized characteristics.

An integrated system for obtaining the characteristics of specific corona losses from voltage (CSCL) has been developed based on the approximated dependencies [12] of the method of generalized corona loss characteristics. The described technique is implemented in the form of the CORONA program. According to the developed program, the specific characteristics of corona losses of the form (17) were obtained for some flat overhead lines for the middle zone and Western Siberia (Table 1).

The degree of corona loss characteristic from the voltage of the exponential function varies within 5÷7. Large values of the stress degree index refer to good weather. For the average annual CSCL, the degree of stress has a value of 6.

The results of calculating the capacitance of a three-phase line using Maxwell's equations and simplified equations show that the errors in the capacitance of the OL phases are about one percent, the values for the middle phase are 1.2% and for the extreme phases - 2.3%.

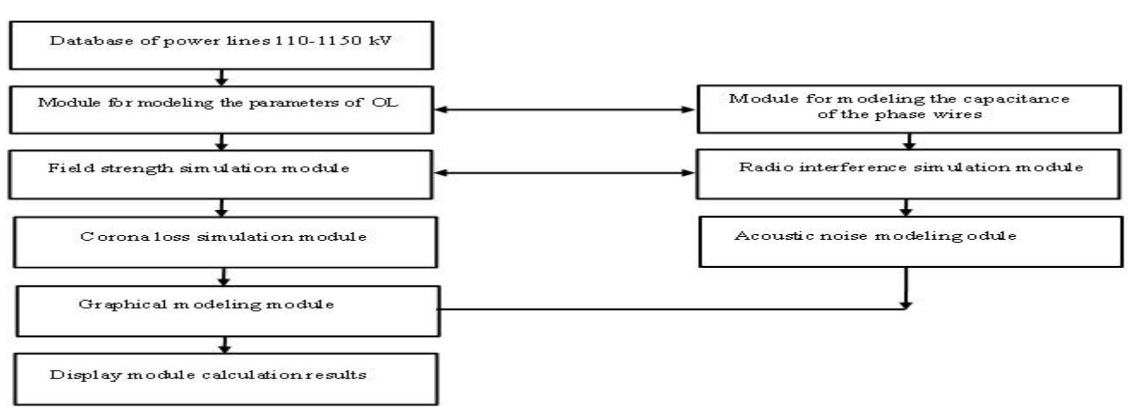

Fig.1. Block seme modeling electromagnetic analysis of the impact of high voltage AC power lines in the environment.

The software package allows you to determine the working capacitances of the phases, the initial and equivalent electric field strengths on the wires, the generalized characteristics of the corona losses for overhead lines with an arbitrary design of split phases and cables; to obtain the specific characteristics of corona losses depending on the voltage in a tabular form, in the form of a polynomial up to the fourth degree and a power function for 4 main and 6 additional groups of weather conditions and average annual losses for flat and mountain overhead lines; determine the additional capacitance caused by corona wires, and the maximum electric field strength allowed under radio interference conditions.

The results of approximation of the power function of the form

$\Delta P_k = a_0 \left(\frac{U}{U_0}\right)^{a_1}$ when the voltage changes in the range from 0.95*U_{nom} to 1.05*U_{nom} are given in the table 1.

Table 1. Results of power function approximation for 500 kV overhead lines with 3AC330/43 in the voltage range from 0.95*UN to 1.05*UN.

Weather type	Approximation function coefficients		Error approximations, %	
	a_0	a_1	Maximum value	Medium quadratic mistake
Good weather	2.36	7.01	0.53	0.31
Mist	4.84	6.19	0.02	0.01
Dry snow	10.17	7.29	0.55	0.32
Rain	33.26	5.56	0.69	0.39
Grainy frost	91.79	4.81	0.49	0.28

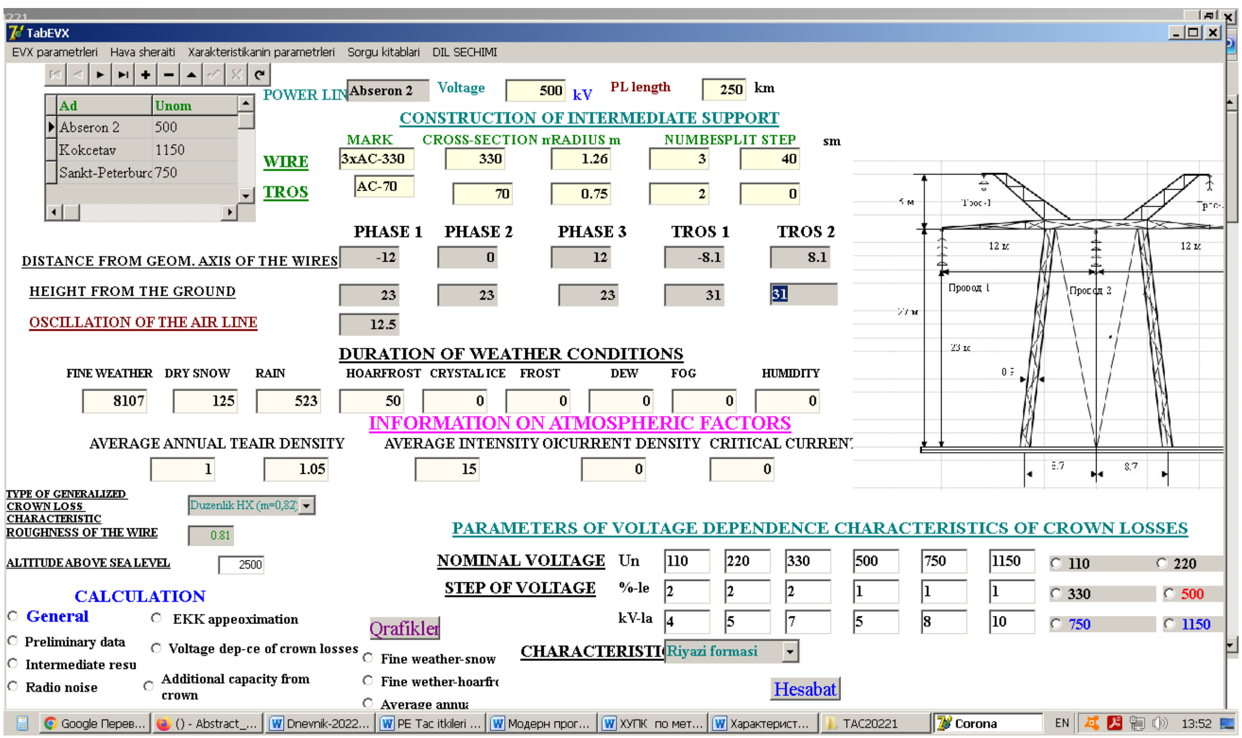

Fig. 2. Screen form for input and display of intermediate support data.

Specific characteristics of power losses from voltage in the form of a table kW/km for 500 kV overhead lines with 3AC330/43 wires are shown in Table 2.

Table 2. Specific characteristics of power losses from voltage in the form of a table for 500 kV overhead lines

№	Voltage overhead line, kV	Values of specific corona voltage losses for different weather groups, W/m			
		Good weather	Dry snow	Rain	Grainy frost
1	**475**	1.66	7.04	24.85	71.37
2	**480**	1.78	7.57	26.44	75.27
3	**485**	1.91	8.14	28.09	79.30
4	**490**	2.05	8.76	29.81	83.44
5	**495**	2.19	9.42	31.58	87.70
6	**500**	2.35	10.13	33.41	92.08
7	**505**	2.53	10.90	35.30	96.57
8	**510**	2.71	11.73	37.23	101.16
9	**515**	2.91	12.62	39.22	105.85
10	**520**	3.12	13.57	41.26	110.64
11	**525**	3.34	14.60	43.33	115.51

Dependences of specific corona losses and exponent of corona loss characteristic on voltage for different weather groups shown in table 3.

Table 3. Coefficients of characteristics of specific corona losses from voltage

Voltage overhead line, kV	Wire mark	Splitting step, sm	Dependences of specific corona losses and exponent of corona loss characteristic on voltage for different weather groups									
			Good weather		Dry snow		Rain		Grainy frost		Average annual	
			$\Delta P_{к0}$, Vt/m	ρ	$\Delta P_{к0}$, Vt/m	ρ	$\Delta P_{к0}$, Vt/m	ρ	$\Delta P_{к0}$ Vt/m	ρ	$\Delta P_{к0}$, Vt/m	ρ
330	2AC240/32	40	1.31	7.1	4.72	7.3	15.4	5.7	42.9	4.9	5.2	5.7
	2AC300/39	40	1.01	6.6	3.64	6.7	12.8	6.1	37.4	5.2	4.3	5.8
500	3AC330/43	40	2.39	6.9	10.9	7.3	33.7	5.5	92.4	4.7	11.0	5.6

3.Conclusions

Software has been developed for modeling the effects of corona on wires and the characteristics of corona losses from voltage by a power function and polynomials up to the fourth degree based on the technique of generalized loss characteristics.

The error of approximation by a power function does not exceed 5%. The polynomial of the second degree gives a small error in the range of voltage change ±8% U_N. A polynomial of the third degree gives more accuracy than a power function, when using a polynomial of the fourth degree, high accuracy is obtained.

The software can be used to take measures designed to reduce the electric field of EHV overhead lines when designing and assessing the impact of existing power lines on the environment and the characteristics of voltage corona losses.

Characteristics of specific corona losses from voltage can be used in existing programs for calculating steady-state conditions and optimizing electrical networks.

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