

MECHANICAL AND THEORETICAL ENGINEERING

**S. N. Litunov, H. A. Hilal, T. F. Matar**

Experimental determination of pressure in screen printing apparatus of high accuracy

Using an experimental setup, the effect of the viscosity of the ink, the speed and angle of inclination of the metering squeegee on the pressure in the printing ink when filling holes of 65 microns and 85 microns in diameter is studied. The experiments are performed using strain gauge methods and special software. It is found that for holes, with a diameter of 65  $\mu\text{m}$ , a length of 50  $\mu\text{m}$  and a diameter of 85  $\mu\text{m}$  and a length of 150  $\mu\text{m}$ , the pressure varies from 1360 Pa to 4709 Pa, or from 33,8 % to 40,3 %. The results are necessary to verify the adequacy of the paint flow model in front of the dosing squeegee.

**Keywords:** screen printing, printed form, dosing squeegee.

**V. V. Syrkin, I. A. Abramova, N. V. Zakernichnaya**

Calculation of errors in division of flows in regulators with elastic regulating element under variable loads

A method of calculating flow dividers with an elastic regulating element in terms of varying loads on the executive bodies of technological machines, the presence of which significantly affects the accuracy of actuating movements in existing structures, is described. The elastic regulating element allows to simplify the design of the divider, to increase its speed and improve the accuracy of the executive movements of the working bodies.

**Keywords:** flow divider, synchronization of executive movements, regulating body with an elastic element.

**V. V. Syrkin, I. N. Kvasov, Yu. F. Galuza, O. S. Dyundik**

Method for calculating flow dividers with elastic regulatory body

The method of calculating the flow divider with an elastic regulating element which with respect to the existing structures has a compact structure and increased reliability is considered. The introduction of the regulatory body in the form of elastic support for the effective compensation of the error of dividing the flow, resulting from the action of hydrodynamic forces.

**Keywords:** flow divider, synchronization, elastic control element, pressure, fluid flow, error of dividing the fluid flow.

**I. A. Kyzmenko, A. B. Yakovlev**

Computation of static characteristic of fuel supply system into unitary gas generator of liquid rocket engine

There are considered the static characteristics of a unitary-component gas generator for the turbine power supply and the control throttle of the liquid rocket engine supply system. There are shown the equations describing the processes occurring in the unitary gas generator and the control throttle are given and the graphic dependencies. A mathematical model of the processes is presented, which allows to reveal the main regularities of the influence of command values and external influences

on the output value. The results presented in this paper allow us to obtain the dynamic characteristics of the elements of a liquid rocket engine.

**Keywords:** liquid rocket engine, unitary fuel, liquid gas generator, throttle.

**D. A. Blokhin, A. G. Koltsov, M. A. Totik, A. G. Drobotun**

Methods for reduction backlash of grinding CNC-machine tool

In the article issues of improving the positioning accuracy and interpolation of circular traffic for a VZ700F4 grinding CNC-machine tool with a Siemens 802D are discussed. A method for determining inaccuracies in real time in various modes using a laser interferometer and ballbar is considered. Reduction of the measuring time is approximately 40–50 %. The indicators of positioning accuracy, the main reasons of the difference between real and program movements are investigated. The effect of ball screw repair with replacement of the X-axis sliding nut on the accuracy of the machine tool movements is described.

**Keywords:** grinding machine, CNC-machine adjustment, laser interferometer, backlash reduction, ballbar.

#### **ELECTRICAL ENGINEERING. POWER ENGINEERING**

**A. V. Bubnov, A. V. Nikonov, A. N. Chetverik, Yu. V. Kreidunova**

Improving dynamics of synchronously-inphase electric drive in transient synchronization and phasing modes

The synchronously-inphase electric drive built on the basis of electric drive with phase synchronization is widely used in thermal imaging and laser scanning systems due to the high accuracy and dynamic characteristics in a wide range of adjustment of the angular velocity. The purpose of the article is to develop ways to control a synchronous-in-phase electric drive in synchronization and phasing modes, which allow to improve the dynamic performance of the electric drive. The method of quasi-optimal speed phasing of electric drive is improved. Recommendations on the organization of transient processes with an abrupt change in the reference signal are formulated. The authors propose circuit implementations of a pulse frequency-phase discriminator with an extended linear zone in the phase comparison mode, which allow to improve the dynamics of the electric drive in the synchronization mode.

**Keywords:** synchronously-inphase electric drive, pulse frequency-phase discriminator, logical comparison device, discriminator, linear zone.

**V. N. Goryunov, A. V. Ded, E. P. Gilenko, Yu. P. Lavrikov, P. S. Smirnov**

The analysis of data on losses of electric energy in branches of PJSC «IDGC of Siberia» from 2010 for 2017

In the article results of the analysis of data on a holiday of electric energy are presented to network and a holiday of electric energy from network of the main branches of the network company PJSC «IDGC of Siberia» on all levels of tension. Average values of indicators of the actual losses are defined and assessment of level of losses of the electric power of the main branches of PJSC «IDGC of Siberia» on compliance of target indicators of the energy strategy of development of Russia till 2030 is made.

**Keywords:** electric power losses, electric power quality control, development strategy, electricity supply.

**V. Z. Kovalev, R. N. Khamitov, E. M. Kuznetsov, V. V. Anikin, B. O. Bessonov**

Determination of operational parameters of submersible induction motors by identification parameters of T-shaped equivalent circuit

The method of determining the operating parameters of submersible induction motors (AED) – stator current, output power, efficiency, power factor, etc. through the parameters of the T-shaped equivalent circuit with a single-circuit rotor is considered. For the practical implementation of the methodology is developed by the program SHEM\_PAR in Matlab 7. There are presented results of determination of operational parameters in the SEM types of ED(T)12-117-380, 1ЭД(T)45-117-1000, 1ЭД(T)63-117-1000 confirming the effectiveness of the program SHEM\_PAR and expediency of its application at the enterprises for repair of submersible equipment to identify and control the parameters of SEM with the aim of improving the turnaround time of operation of the equipment for oil production.

**Keywords:** active and inductive resistances of stator and rotor windings.

**S. S. Girshin, V. M. Trotsenko, V. N. Goryunov, O. V. Kropotin, A. O. Shepelev, V. A. Tkachenko**

Simplified formula for active power load losses in transmission lines taking into account temperature dependence

Application of the simplified formula for calculation of losses of active power in power lines taking into account temperature in the conditions of a stationary thermal mode is considered. Results of comparison of the losses calculated by the simplified formula and on the basis of the solution of the full equation of thermal balance for wires of various types are given. The dependencies of the calculation error on the load current with and without solar radiation are constructed and analyzed.

**Keywords:** transmission lines, power losses, temperature dependence of active resistance.

**O. A. Lysenko, A. V. Simakov, S. A. Gorovoy**

Improving efficiency of pumping units in the oil refining industry

The article deals with the issues of increasing the energy efficiency of the electric drive of the pumping unit. The aim of the work is to determine the effectiveness of the use of the frequency-controlled electric drive of the pump unit control. The issues of optimizing the consumption of energy resources during the technological process are of interest in connection with the growing requirements for the energy efficiency of electrical equipment. The work is carried out the construction of the main characteristics of the pumping unit, as well as the calculated parameters of energy consumption. Calculated data, taking into account the features of the methodology used, are correct. As a result of the work, the low efficiency of operation of the object of study is determined. A method for determining the feasibility of using a frequency drive is presented.

**Keywords:** energy efficiency, oil refining, electric drive, flow throttling, centrifugal pump.

**O. A. Lysenko, A. V. Simakov, M. A. Kuznetsova, A. V. Nikonov**

Calculation of mechanical characteristics of asynchronous submersible electric motor by finite element method

The article deals with the determination of the parameters of electric machines of alternating current from the electric drive of an electric centrifugal pump. The aim of the work is to build a mechanical characteristic of an asynchronous submersible motor using modern software. The application of modern software for modeling is of interest. In the course of the work, the dependence of the asynchronous machine torque on the rotation speed is constructed on the basis of analytical dependencies and mathematical modeling by the finite element method. The modeling data, taking into account the error and assumptions made, are correct. The result of the work is the method of calculating the mechanical characteristics of asynchronous electric machines with a squirrel-cage rotor based on the simulation in the program Elcut 6.2.

**Keywords:** mechanical characteristic, electric drive, submersible motor, mathematical model, finite element method

**A. G. Lyutarevich, M. A. Basmanovskiy, V. P. Sershanskiy, E. P. Zhilenko**

Investigation of lightning protection of open switchgears of power stations and substations

The development of methods and algorithms for calculating elements of protection of energy facilities is always one of the most important scientific and technical problems. Remains relevant as the development of new technical solutions, as well as the improvement of the regulatory framework. The indicated tendencies are also valid for the lightning protection of power stations and substations. The purpose of this study is to review the existing methods for determining the parameters and elements of lightning protection using the example of calculating a typical substation. As a result of the study, the methods of designing and determining the effectiveness of lightning protection of power stations and substations are considered. The results of the calculation of the lightning protection of the open switchgear of a transformer substation 110/10 kV are presented. The results of the study can be used to develop algorithms for determining the parameters of lightning protection, as well as software for automated calculation of the protection of open switchgears of power stations and substations from direct lightning strikes.

**Keywords:** protection zone of lightning conductor, methods of calculating lightning protection, calculation of lightning protection switchgear.

**A. G. Mikhailov, O. V. Vdovin, E. N. Slobodina**

Intensification of heat exchange in fire-tube boiler using nanofluid as heat transfer fluid

The article suggests the solution of problems related to the intensification of heat transfer from the high-temperature organic heat transfer fluid through the use of nanoparticles. The criterial equation describing heat exchange in the volume of a high-temperature organic heat transfer fluid under natural convection for clean and nano- fluids is presented. The basic equations for the thermal calculation of the fire-tube boiler are considered. Based on the results of the calculated experiment, graphs of the dependence of heat transfer coefficient from the heat transfer fluid and the boiler furnace, boiler wall temperature, heat transfer coefficient for gas tube bundle, area of gas tube bundle on the volume fraction of nanoparticles in the heat transfer fluid.

**Keywords:** high temperature heat transfer fluid, fire-tube boiler, nanofluid, wall temperature, coefficient of heat transfer.

**D. S. Osipov**

Development of criterion for choosing optimal type of mother wavelet in problem of calculating active and reactive power at power systems

The paper presents a method for calculating the active and reactive power of higher harmonics using wavelet transform. The calculation of components of power of harmonics will improve the accuracy of the technical and economic assessment of the introduction of filter-compensating devices when solving the actual problem of harmonic suppression and loss reduction in current-carrying parts. A criterion has been developed for choosing the optimal type of wavelet in the problems of calculating and modeling the non-sinusoidal modes of power supply systems. The criterion is based on the determination of the local energy density of the harmonic group under study and on the possibility of carrying out the inverse wavelet transform (signal reconstruction) with the smallest error.

**Keywords:** wavelet transform, non-sinusoidal modes, higher harmonics, spectrum energy, wavelet amplitude response.

**D. S. Osipov, N. N. Dolgikh, S. A. Gorovoy, V. E. Poplavskaya**

The analysis of additional losses from higher harmonics in 380 V networks using packet wavelet transform algorithms

The paper presents a method of analysis of non-stationary non-sinusoidal modes of electric power systems (EPS) based on the packet wavelet transform. Wavelet transform (WT) in contrast to the Short Time Fourier transform allows analyzing of higher harmonics in three-dimensional plane (amplitude, frequency, time). Absences of necessity to select window width when implementing WT avoids the negative effect of spectrum leakage. The use of WT calculation of higher harmonics will improve the accuracy of the assessment additional losses in EPS and develop events to improve energy efficiency of power systems.

**Keywords:** Wavelet transform, non-sinusoidal modes, higher harmonics, Fourier transform, unbalanced phase load, LED-based lighting.

**P. V. Rysev, D. V. Rysev, K. S. Shulga, O. V. Meshalkin**

Determination of resonance frequencies of electromechanical vibrations of gas turbine power stations

The article deals with the problem of occurrence of electromechanical resonance interactions in turbogenerators of gas turbine power stations of autonomous power systems of oil and gas fields, leading to torsional vibrations of shaft pipelines. The danger of this phenomenon is estimated. We consider two design scheme for the simulation of resonance. There is determined the natural frequencies for each of the calculation schemes are compared with the data of actual accidents the estimated trends of changes of natural frequencies depending on the power and massiveness of the turbines.

The authors substantiate the danger of such regimes, as well as the need to develop special measures aimed at preventing and eliminating the modes of Electromechanical resonance.

**Keywords:** electromechanical resonance, torsional vibrations, gas turbine power station, electric power system.

### **A. A. Tatevosyan**

Selection of optimal design, experimental study and mathematical modeling of magnetic field of low-speed synchronous generator with permanent

Increased scientific and practical interest in the development, design, research and implementation of low-speed permanent magnet synchronous generators is caused by the need to equip and fill various sectors of the national economy with efficient renewable energy sources based on the principles of wind, hydro and pneumatic energy. The impetus to the creative thinking of domestic and foreign science on the creation and introduction into production and life of new types of designs of magnetoelectric machines with excitation from permanent magnets is the emergence on the consumer market of a wide range of highly coercive permanent magnets based on rare-earth elements from neodymium-iron-boron alloy (NdFeB). In this paper, the design of a low-speed permanent magnet synchronous generator is proposed taking into account the full list of requirements for renewable energy sources accumulated by practical experience in creating such electromechanical converters. Along with the geometry description, the article presents the results of mathematical modeling of the magnetic field of a low-speed synchronous generator using the ANSYS (Maxswell) package confirmed by experimental studies of a prototype.

**Keywords:** design of a prototype of a low-speed synchronous generator, horseshoe-shaped electromagnets with a U-shaped core and coils, high-coercive permanent magnets in the form of disks, simulation of a magnetic field, idle mode and short-circuit of a synchronous generator.

### **A. S. Tatevosyan, V. V. Pedder, N. D. Buryakov, I. A. Pastushenko**

Experimental technique of identification of high-coercive permanent magnets

The stand is developed and the experimental technique of identification of pilot batch of the high-coercive permanent magnets made of the same brand of alloy neodymium – an iron-pine forest (NdFeB) is offered. Prototypes of permanent magnets have the form of a disk and a rectangular prism, the axial direction of magnetization. Criterion of identification of permanent magnets in each pilot batch is their identical volume magnetization which is considered by a mean square deviation of the constructed experimental curve dependences of electromagnetic force of interaction of each prototype of a permanent magnet with the magnetic reflector at change of distance between them. As the magnetic reflector more powerful permanent magnet having the form of a disk and height exceeding height of a prototype of a permanent magnet is used. The neglect the procedure of identification of permanent magnets in pilot batch leads to violation of work of electromagnetic systems with their participation, so for example when developing inductors of synchronous electrical machines on the basis of permanent magnets beats of a shaft, the increased vibrations of working bodies, increase in radial and axial load of bearings are observed, service life and failure in the functioning of electrical machines during operation is reduced.

**Keywords:** high-coercive permanent magnets, alloy neodymium – an iron-pine forest, a prototype in the form of a disk and a rectangular prism, the experimental stand, electromagnetic force.

### **D. G. Safonov**

Simulation modeling of distribution network with arc-suppression coil

The article presents a simulation model of a three-phase distribution network with compensated neutral together with an arc-suppression control system. The control system is based on the principle of creating an artificial neutral displacement and the subsequent tuning of the reactor according to the extreme of the zero-sequence voltage curve.

In addition to the network parameters in the model you can change the size and nature of the load, which will allow you to check the operability of the control system of the arc-suppression coil in the event of a single-phase earth fault.

**Keywords:** arc-suppression coil, compensated neutral, control system, distribution network, zero sequence voltage.

**D. V. Kovalenko, E. A. Pugacheva, D. A. Rogozina, A. E. Fridrikh**

The review of current studies on identification of resonant modes arising in elements of electrical networks of industrial enterprises and household sector

The authors made the review of literature on the identification of potential resonant modes that may arise in the networks of industrial enterprises and non-production loads. In some cases, research teams presented ways to prevent the fulfillment of resonant conditions. The occurrence and influence of resonant overvoltages on the structural elements of electrical machines are considered, technical solutions for diagnosing machines are proposed, and methods are presented to improve the accuracy of identifying internal resonant frequencies near which overvoltages will occur.

**Keywords:** resonant mode, resonant overvoltage, analysis and identification of resonant modes.

**D. V. Kovalenko, P. S. Smirnov, D. V. Dubrovskiy, M. S. Matveeva, N. V. Rubanov**

Measurement of quality indicators of electrical energy in computer class network and development of measures to filter higher harmonics

In the work the measurement of electrical energy quality indicators (PEC) of a computer class power supply system of one of the educational institutions of the city of Omsk using electrical energy quality analyzers is carried out. The composition of each personal computer includes a switching power supply. It is the source of higher harmonics that violate the standards of the SCE, established by GOST 32144-2013. To eliminate the influence of higher harmonics on the power supply network elements and prevent the occurrence of resonant modes, the authors of the article proposed the calculation of parameters and the installation of passive filters in the network under study. Developed mathematical modeling in the software package MATLAB-Simulink confirms the author's hypothesis about the effectiveness of the use of filters.

**Keywords:** power quality indicators, non-sinusoidal mode, resonant mode, higher harmonics filtering.

**G. A. Koshuk, B. A. Kosarev, V. K. Fedorov**

Optimized voltage of energy source definition for power system with dispersed generation

The article is concerned with design of power system with dispersed generation, more precisely, the optimized voltage of energy source and distribution electric networks definition, because the power system with the optimized voltage application has minimal costs. The purpose of article is development of an algorithm and the program of calculation of the optimized voltage of power system with dispersed generation. The algorithm is realized in the computer-aided design MathCAD. Calculation data agree within the technical support.

**Keywords:** dispersed generation, optimized voltage, electric networks, micronetwork, power source, electrical installation, technology of generation.

**D. Yu. Rudi, A. I. Antonov, M. G. Vishnyagov, S. V. Gorelov, D. A. Zubanov, A. A. Ruppel, E. Yu. Ruppel**

Study of higher harmonics in low voltage electrical networks

This scientific article describes the test carried out on a complete transformer substation-2 10/0,4 kV. A method for processing the results of research obtained during the experiment is described. All indicators of the total harmonic components of the voltage are processed by means of a software product in the LabVIEW development environment. The analysis of compliance of this indicator of quality of electrical energy at each phase with the requirements of GOST 32144–2013 has been carried out.

**Keywords:** quality of electric energy, total harmonic component, harmonic, electromagnetic interference.

**I. V. Prisukhina, D. V. Borisenko**

Machine state classification of electric track circuit by means of support vector machine

The effectiveness of a track circuit monitoring system can significantly improve with the implementation of the automatic data analysis. As part of this functionality, in our previous publication, we proposed the track circuit state classifier based on the logistic regression. However, this classifier has some limitations. In this article, we propose a more advanced classifier based on the support vector machine (SVM). We describe theoretical principles on which the classifier is built and demonstrate its work on synthetic rail circuit state data. We also show that the SVM track circuit state classifier with the Gaussian kernel requires fewer features than the classifier based on the logistic regression.

**Keywords:** railway signaling, electric track circuit, machine learning, classification, logistic regression, support vector machine.

**N. A. Tereshchenko, K. I. Nikitin, S. S. Makovetskiy, E. P. Zhilenko**

Calculation of additional resistance and design of sensor of current of leakage of high-voltage insulator

The article presents the results of laboratory tests conducted to determine the order of the leakage current to calculate insulation resistance without turning off the voltage. The materials are selected to create additional resistance. There is calculated static and dynamic loads on the structure. There is defined section of the terminal resistor.

**Keywords:** leakage current, insulators, alternating voltage, scale resistor.

**V. A. Tkachenko, O. V. Kropotin, A. O. Shepelev, V. O. Kropotin**

Mathematical model of cable power line with XLPE insulation with underground installation

This paper considers mathematical modeling of a stationary thermal field in the cross section of a single-conductor cable with XLPE insulation. The equivalent circuit of thermal processes is made using the method of homogeneous bodies and it includes dielectric losses, it takes into account the ambient temperature, as well as the temperature dependence of the active resistance of the cable core. The assessment of the adequacy of the mathematical model is performed by comparing the obtained results with the calculation of thermal and electrical processes using the finite element method carried out in the software ANSYS Workbench. The resulting mathematical model can be



used to control the capacity of cable lines with XLPE insulation and limit their service life due to temperature aging of insulation.

**Keywords:** cable with XLPE insulation thermal, equivalent circuit, thermal resistance.

**A. A. Bubenchikov, T. V. Bubenchikova, E. Yu. Shepeleva**

The analysis of foreign experience in study of wind power generation systems

The paper presents a brief analysis of the configuration options for the energy conversion circuits of modern wind power plants. The characteristic types of generator systems for wind turbines are considered and the pros and cons of using various types of electrical machines as generating devices for wind turbines are analyzed. The vector of development of wind turbines is defined in terms of the choice of the type of generator system. The article describes the proposed future generation systems and lists their advantages and disadvantages compared to the currently used generating systems.

**Keywords:** wind power plant, generation system, generator, gearbox.

**K. V. Kenden, K. B. Sagaan-ool, Yu. Ch. Ondar**

Problems and prospects of energy development complex of the Republic of Tyva

The lack of own generating capacities in a region is the main limiting factor for the socio-economic development of the region. These regions include the Republic of Tuva, the power supply of which is completely dependent on Krasnoyarsk and Khakas energy systems. The article analyzes the energy complex of the Republic of Tyva, on the basis of which the features and problems of the functioning of the electric power complex Tyva. The possible options of covering the energy deficit of the region are presented.

**Keywords:** power system, Tyva, energy deficit, wear and tear, consumer power supply.

**I. S. Lebedev, A. A. Bubenchikov, A. A. Zakharov, T. V. Bubenchikova**

Development of power generating section of autonomous wind energy systems for regions of continental climate with low wind pressure

This article describes a design option for an energy generating section of a multi-tiered type of a wind power installation with vertical axis of rotation, the design of which makes it possible to obtain the highest efficiency values relative to the known analogues with placement in areas of unstable-low wind pressure. The results of mathematical modeling and the principle of operation of the tiers of elements of power generating section with the vertical axis of rotation both individually and in combination with each other forming a complete execution are considered. It is proposed to create a five-channel confused tier of concentration and reorientation of the air flow moving along the trajectory of 3-dimensional logarithmic spiral. The main and secondary acceleration zones with the placement of the power take-off unit and the dispersion zone of the spent air flow were designed. The total values of average coefficients of the acceleration of the air flow passing through the power generating section at different speeds of the incident flow are determined. The analyzed version of the design does not require orientation in wind and has the potential to stabilize oncoming air flow.

**Keywords:** confuser, concentrator, acceleration of air flow, dispersion of air flow, wind turbines with vertical axis of rotation, power generating section.

**INSTRUMENT ENGINEERING, METROLOGY  
AND INFORMATION MEASURING EQUIPMENT AND SYSTEMS**

**A. A. Kuznetsov, A. S. Bryukhova**

Determination of quantitative content corrosion products on concrete products surface

The article deals with the processes of corrosion in reinforced concrete supports of the catenary and describes the reactions accompanying corrosion of steel reinforcement. The experiment of electrochemical corrosion made of samples with varying degrees of corrosion of steel reinforcement is described. Samples with different corrosion degree of steel reinforcement are made. Spectral analysis is performed to determine the quantitative content of corrosion products on concrete surface. The analysis of results confirms the dependence of the corrosion products concentration on the concrete surface with the removal of metal from the steel reinforcement volume. The calibration dependence of the iron determination on concrete surface is obtained. Conclusions are made about the possibility of using mobile spectral analyzer in conjunction with the presented methodology.

**Keywords:** reinforced concrete, corrosion products, sample surface, diagnosis of corrosion condition, calibration dependence, spectral analysis.

**A. I. Blesman, R. B. Burlakov**

The method for fabricating photocell based on two Schottky barrier contacts Al-*p*-Si and Ti-*p*-Si

The task of studies is a development of the structure and way of the fabrication of the photocell capable to take a radiation or in near infrared region of the spectrum (1–1,4) microns, or in the field of (0,5–1,4) microns. The way of fabrication and results of studies of photoelectric features of two spectrum photocell based on two Schottky barrier contacts Al-*p*-Si and Ti-*p*-Si situated on opposite parties Si plate is considered. It is shown that removing violated layer on surface of the silicon plate leads to significant increase voltage of the idling and current of the short circuit of the contact Al-*p*-Si situated on this surface and illuminated through the silicon plate.

**Keywords:** method of fabricating the photocell, p-type silicon, Schottky barrier contacts.

**R. B. Burlakov**

Contact resistivity measurement of silicide ohmic contacts to silicon *p*-type by Transmission Line Method

Determination of contact resistivity  $\rho_K$  by Transmission Line Method is considered. This way is used for making and measured silicide ohmic contacts to silicon *p*-type (with nominal resistivity  $\rho = 10 \Omega \cdot \text{cm}$ ) on the base of systems PtAg, PdAg and NiAg. It is shown that system PtAg has the most low values  $\rho_K = (5,5 - 5,6) \cdot 10^{-2} \Omega \cdot \text{cm}^2$ .

**Keywords:** contact resistivity measurement, TLM-method, silicon *p*-type, silicide ohmic contacts.

**V. F. Kovalevskiy, S. B. Skobelev**

Experimental studies of electrohydraulic effect application of L. A. Yutkin for removal of flares from terminals of plastic details

The article describes the description of the electrohydraulic effect of L. A. Yutkin. The electrical schematic of the laboratory installation for cleaning the terminals of plastic parts is presented, as well as the design of the pilot plant and interchangeable devices used to remove the flare from the

terminals of the plastic parts. The results of experimental studies on the preliminary and final cleaning of the terminals of plastic parts from the flare are presented. For complete removal of a thick flare from the surface of the outlet and from the holes, it takes about 3 to 5 seconds for the part. The complete removal of the film of the flare at the output of the part takes 10–20 seconds.

**Keywords:** conclusions of plastic parts, electrohydraulic effect, hollow, spark discharge, hardening.

**O. V. Krivozubov, Yu. G. Kryazhev, I. V. Anikeeva, N. A. Davletkildeev, D. V. Sokolov, V. A. Licholobov**

Formation of nanostructured carbon layers on silicon substrate using polyvinyl chloride as carbon precursor

The carbon layers are obtained by low-temperature (200–400°C) thermal transformation of polyvinylenes deposited on silicon substrates by spin-coating method. Polyvinylenes are obtained by dehydrochlorinating polyvinyl chloride under the action of aniline in dimethyl sulfoxide. Dehydrochlorination of the polymer is carried out in the presence of  $\text{Fe}(\text{NO}_3)_2$  for the introduction of the metal into the carbon layer composition. The morphological features of the formed layers structure are investigated by the method of atomic force microscopy (AFM). It is found that carbon layers without metal additives are macroporous with through pores of submicron sizes. Solid carbon layers with metal-containing nanoparticles embedded in the carbon matrix are formed in the presence of iron. The obtained results can be used to improve the element base of microelectronic devices.

**Keywords:** nanostructured carbon films, PVC, polyvinilen carbonization, spin-coating method, atomic force microscopy.

**Ya. V. Kryukov, A. Ya. Demidov, D. A. Pokamestov, E. V. Rogozhnikov, R. R. Abenov**

Non-orthogonal multiple access method with power division

In the article the method of non-orthogonal multiple access with the power division of user channels for wireless communication is considered. Comparison of the characteristics of channel capacity and noise immunity for PD-NOMA and OFDMA communication channels obtained is presented. The method of sequential interference cancellation SIC, which is used to demodulate PD-NOMA signal, is considered. The effectiveness of the PD-NOMA method is demonstrated and the expediency of its use at the physical level of wireless broadband access communication systems is explained.

**Keywords:** non-orthogonal multiple access, channel multiplexing, broadband wireless communications, channel capacity

**E. V. Leun**

Questions of construction of jet-drop optical measuring systems: principle and modes of operation, capabilities and basic characteristics

The article is devoted to optical measuring systems using three types of hydraulic streams as optical elements: an unmodulated jet and two parts of a modulated jet in the mode of forced capillary decay: the unbroken part of the jet and the drip stream. A classification of jet-drop optical measuring systems (JDOMS) has been carried out, their schemes for measuring product displacements and surface irregularities are presented, which implement a hydrojet interference

method for measuring linear dimensions of products and the like drop microscope. The questions of light transmission and control of parameters of hydraulic streams are considered.

**Keywords:** jet, drop, product size, product surface, optical measurements, interferometer, microscope.

### **G. V. Nikonova**

Metrological reliability of automated control systems and diagnostics of electronic equipment products of UHF band

The material of the article reflects the results of the analysis and gives recommendations for ensuring the reliability of the results of tests of BIS and VLSI UHF bands in automated control systems and diagnostics. The article shows the solution of the tasks of metrological certification of the channels of the test system in the formation of test actions of a given amplitude synchronized with the reference channel signal. Recommendations are given to ensure metrological reliability in measuring the amplitude and time parameters of the signals-responses from the test object. The technique for estimating the requirements for verification equipment by amplitude and time parameters is given. The types of specific measuring instruments that allow to ensure the reliability of testing of electronic equipment of the UHF range are given.

**Keywords:** UHF range, electronic products, test pulse signal, amplitude setting error, synchronization error.

### **A. E. Samotuga, R. A. Ahmedzhanov, A. A. Fedotov, A. A. Pyatkov**

Full pipeline oscillation model under impact

An urgent task is to obtain experimental data on pipeline vibrations to assess the effectiveness of vibro-acoustic methods for monitoring its condition, while access to the object is often difficult. The paper presents an improved model, on the basis of which it is proposed to calculate the elastic oscillations fixed on the surface of the pipeline as a result of impact. The assessment of the adequacy of the obtained analytical expression is carried out by comparing the calculated signal with the empirical one obtained on the active object.

**Keywords:** elastic vibrations, transverse vibrations of the pipeline, shock impact, model of vibrations of the pipeline.

### **A. E. Samotuga, A. A. Fedotov, R. A. Akhmedzhanov, A. A. Pyatkov**

Evaluation of adequacy of analytical expressions for vibrations of pipeline under shock effect

The paper presents two analytical expressions for modeling pipeline oscillations as a result of a shock effect, which allow testing the vibroacoustic signal processing algorithms to detect unauthorized connections. The calculation and assessment of the adequacy of the models by comparing the pulse shapes and their amplitude-frequency spectrum with the experimental ones obtained on a five-meter pipe and the operating pipeline 200 m long has been implemented. The model designated in the paper as «complete» shows the most reliable results when calculating the oscillations of both the pipe layout and the long active pipeline with interference applied.

**Keywords:** model of pipe oscillations, lateral vibrations of the pipeline, unauthorized impact on the pipeline, elastic vibrations.

## INFORMATION TECHNOLOGY

**G. N. Boyarkin, K. V. Kravchenko, O. G. Sheveleva**

A systematic approach to planning and managing business processes for training highly qualified personnel

This article considers the problem of increasing the effectiveness of training in graduate school by solving the optimization problem of distributing applicants by scientific supervisors taking into account the potentials of the participants in the learning process. A model of decomposition of business processes for training highly qualified personnel has been built, the potentials of an incoming and scientific supervisor are defined, a mathematical model of the optimization task of distributing applicants by scientific supervisors has been developed, and requirements have been proposed for the software implementation of this task. The paper proposed a logical description of the distribution model of applicants for scientific leaders and the structure of its mathematical description.

**Keywords:** business process, optimal distribution, hierarchy analysis method, potential participant in the learning process, mathematical modeling.

**A. A. Magazev, A. S. Melnikova**

Construction of security range for information system by averaged dynamics method

In this work, a model of an information system, each element of which is exposed to Poisson flows of security threats, is considered. With help of Markov processes theory, the averaged dynamics of the system is described. The values range of model inner parameters for which the number of break down elements does not exceed a fixed value in a given time is constructed.

**Keywords:** Markov process, Poisson flow, averaged dynamics method, security range.

**V. G. Khomchenko, I. M. Zuga, A. N. Kuzhel, A. O. Stroev**

Qualitative research of routing methods based on wave algorithm and algorithm  $A^*$  for industrial plants

Based on the example of two typical arrangements of industrial companies and application of von Neumann and Moore neighborhoods for wave algorithm and  $A^*$  algorithm we conducted an analysis of impact of routing method and dimension of discrete operational field on the percentage of its coverage, on the arrangement of routes and time expenditure for calculations. It is stated in particular that the path for routes arrangement is influenced not only by the synthetic method but in some cases also by the applied dimension of discrete operational field grid. We revealed the dependency between computation time and grid dimensions. We provided diagrams for the length of routes obtained at various routing methods and grid dimensions.

Computational experiments are conducted at discrete operational field with grid dimensions of 40, 20, 10, 5, 2 and 1 pixel.

**Keywords:** wave algorithm,  $A^*$  algorithm, von Neumann neighborhood, Moore neighborhood, routes arrangement, routing time.

**A. A. Lavrukhin, A. V. Kochekov, Yu. A. Bezrukov, L. A. Denisova**

The analysis of signal amplitude estimation methods when determining parameters of power quality

The article presents the results of model studies of methods for controlling the quality of electrical energy (applied to a traction substation) in the process of its conversion, distribution and power supply to traction and non-traction consumers. To identify the most accurate method for finding the amplitude of the signal, algorithms based on the standard Fourier and wavelet transform – a transformation with a constant and adaptive width of the wavelet window – are compared. The prospects for using algorithms to control the quality of electrical energy in the presence of overvoltage, voltage dips and rapidly changing voltage levels are considered. Studies are performed by the method of mathematical modeling using an interactive environment for scientific and engineering calculations MATLAB. The experiments reflect the prospects of using wavelet analysis to estimate the amplitude of the signal.

**Keywords:** adaptive wavelet analysis, energy quality parameters, computer simulation, electrical signal modeling, electrical energy parameter estimation, MATLAB simulation.

**I. V. Revina, G. N. Boyarkin**

Simulation of production process manufacturing parts

The organization of the production process of manufacturing parts may be multivariate. Using optimization parameters – the maximum possible amount of manufacturing of suitable parts and maximum equipment load (i.e. maximizing profit), as well as limitations – reject rate, the possibility of reprocessing parts in the simulation system of Arena Rockwell Soft various models are developed that revealed bottlenecks in the organization of the production process. Consideration of the models allowed us to estimate: the workload of the machines, the production of suitable parts, the average length of time the parts are in the production process, the average number of parts in the queue, and the profits and losses during the production process. As a result of the simulation, it is shown that the most optimal form of organization of the production process, which increases the profit by 1,45 times, is a two-subject production line.

**Keywords:** simulation modeling, production system, simulation model, parts manufacturing, production organization.

**A. N. Florensov**

About expansion of information concept by modern means of informatics

The analysis of a information concept taking into account the last achievements in theoretical informatics is carried out. It is shown that the definition which has developed for technical science based on the display of interpretation of messages in information does not keep within classical representations of mathematics, it is formalized considering only static sets. In informatics the operating sets of messages and a set of images of interpretation are dynamic sets of conditions of objects. Information aspect of communications of elements is essentially dynamic and the nature of change of a set of the interpreted messages and images of interpretation is a being of receiving and information processing.

**Keywords:** information, message, interpretation, image, dynamicsets.

**G. D. Anisimova, A. V. Myshlyavtsev, M. D. Myshlyavtseva**

Connection of critical phenomena for Langmuir-Hinshelwood mechanism with the type of adsorbed overlayer phase diagram: square lattice, additive gas mixtures

The lateral interaction influence on the steady-state multiplicity domain for Langmuir-Hinshelwood mechanism on the square lattice for some sets of interaction energies has been studied. The set of lateral interactions has been chosen in such way as to completely cover previously unexplored parameter areas. The aim of the work is to complete the study of the constructed model for additive mixtures. In contrast to previous works, the splitting of the parameter space into domains with different phase diagrams of the ground state is taken into account explicitly. In order to simplify the analysis, the case of irreversible adsorption for the both species is considered. It is shown that when the system under consideration has two internal steady-states one can nevertheless have different phase diagrams.

**Keywords:** mathematic modeling of adsorption and reaction, lattice gas model, Langmuir-Hinshelwood mechanism, critical phenomena

**E. O. Vikulov**

Research of high load web applications data distribution using neural network technologies

The article proposes an approach to optimizing the distribution of data in the design of high load web applications. A model has been developed that describes the state of the server stations at the current time, which is suitable for further optimization of data distribution. An experiment was conducted on the distribution of the test sample using neural network technologies. The results of the distribution of data on server stations are given. Based on the results of the experiment, conclusions are drawn about the possibility of using neural network technologies in the distribution of data from high load web applications.

**Keywords:** data distribution, neural network technologies, high load web-applications, clusterization, server balancer, Kohonen network.

**P. S. Machulin**

Comparison of options for controlling brushless motor by mathematical modeling

The article discusses the parameters of the engine obtained as a result of mathematical modeling, with different control algorithms, allowing you to see the transients and the nature of the steady motion of the engine with different control options. The simulation is performed at different moments of inertia of the load and different values and nature of changes in the external load.

**Keywords:** mathematical modeling, electric motor, control system, synchronous motor, rotor position sensor.

**P. S. Machulin, P. V. Popov**

Features of control system of electric drive used in electromechanical devices for opening and containing rods of large-sized antennas and solar batteries

The article discusses the features of the automated control system of an electric motor used in electromechanical devices for opening and restraining the rods of large-sized antennas intended for operation in aggressive environmental conditions including vacuum conditions. The use of an electric drive in such devices imposes a number of restrictions on the control system, design and

principle of operation of the electric drive to ensure the necessary reliability and the full performance of the task by the device.

**Keywords:** electric motor, automatic control system, maximum moment limitation, electromechanical devices, reservation.

**N. R. Storozhenko, A. I. Goleva**

Mathematical model and algorithm for monitoring information system parameters

To perform diagnostics and prediction of possible deviations in the operation of information system nodes, the article provides a mathematical and algorithmic description of network monitoring. The developed scheme of the monitoring system and the algorithm for detection and prediction of network failures. They provide a visual representation of the process of monitoring and anomaly detection and ones are necessary for the execution of the software for monitoring system with the functions of equipment diagnostics and with the ability to prediction of the network state in the conditions of changes in the parameters of network devices.

**Keywords:** monitoring algorithm, corporate data network, mathematical model, fault monitoring, anomaly detection, failure prediction.

**A. L. Tkachenko, O. G. Sheveleva**

Improving efficiency of company's software development department

The article deals with the problem of improving the efficiency of an IT company. As part of the process approach using the method of reengineering, the business process of an IT company for the implementation of technical tasks is constructed and analyzed. There is considered optimization by the method of mathematical modeling of the distribution of workflows as one of the methods to improve the efficiency of the IT company.

**Keywords:** business process, business process efficiency, reengineering, optimization of work processes, purposive programming.

**M. N. Yudina**

Software system for molecular networks of cells analysis and modeling

A program system that designed as JAVA class libraries is presented. The developed program system is designed for research of large networks. The capabilities of the developed system for studying molecular networks of a cell are considered in the work. The problems solved by the program system are described. The original algorithms used are characterized.

**Keywords:** molecular networks, software packages for network research, large networks structural characteristic, motifs, random graphs with nonlinear rule of preferential attachment, accelerated algorithms and numerical methods.

**A. V. Zykina, M. Yu. Savelev, T. Yu. Fink**

Multi-level management of oil refining production. Requirements for research tasks

The problem of enterprise management systems automation is particularly relevant for large oil refineries. Moreover, the integrated model of the refinery has a high dimension. Consequently, it is almost impossible to build an optimal management system of the refinery on the integrated model



basis. In addition, it is necessary to take into account disturbances with a high uncertainty and the activity rate. Therefore, the principle of hierarchy is one of the most important principles in the construction of integrated automated enterprise management systems. This article defines the requirements for research tasks of the theoretical developments implementation in the form of mathematical support for multi-level integrated control systems of oil refining production.

**Keywords:** oil refining production, multi-level integrated control systems, automated enterprise management systems, process control optimization.