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# HEAT AND POWER ENGINEERING

УДК 621.165

## NEW STABILIZATION METHODS OF FLOW IN PLANE, CONIC AND ANNULAR DIFFUSER DUCTS OF TURBINES

E.Yu. GRIGOR'EV<sup>1</sup>, A.E. ZARYANKIN<sup>2</sup>, V.V. NOSKOV<sup>2</sup>, D.E.BUZULUTSKII<sup>3</sup>, O.A. TRUKHIN<sup>1</sup>

<sup>1</sup>Ivanovo State Power Engineering University, Ivanovo, Russian Federation

<sup>2</sup>National Research University «Moscow Power Engineering University», Moscow, Russian Federation

<sup>3</sup> Branch of «Inter RAO» «Ivanovo CCGT», Komsomol'sk, Russian Federation

E-mail: rvs@tren.ispu.ru

### Abstract

**Background:** Having analyzed the operation of Russian and Foreign gas-turbine units, the considerable reserve in increasing the technical and economic indexes on diffuser ducts of these units is proved. According to this, the problem of guaranteeing the diffusers vibrational reliability of powerful engineering gas-turbine units which are the part of combined-cycle gas turbines is urgent.

**Materials and Methods:** The results were obtained by full-scale modeling.

**Results:** Direct connection between diffusers vibrational condition and the flow pattern of operating environment in diffuser flow section was established. The authors suggest two methods of vibrational load decreasing in diffuser ducts of the turbine. Length-wide ribbing of diffuser walls, the usage of the shield near diffuser protected wall lead to vibration decrease.

**Conclusions:** The results show that firstly it is necessary to decrease pressure pulses in flow sections to provide vibrational reliability of diffuser exhaust nozzles of gas and steam turbines. It is possible to solve this problem by direct impact on operating fluid flow pattern or by installation of aerodynamic damper near protected diffuser wall.

**Key words:** aerodynamics, diffuser, turbine, exhaust nozzle, control valve, pressure pulses, vibration.

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УДК 621.187.11

## PRACTICAL IMPLEMENTATION OF COUNTERCURRENT TECHNOLOGY OF IONIC EXCHANGE

A.V. ZHADAN<sup>1</sup>, E.N. BUSHUEV<sup>2</sup>

<sup>1</sup> Closed Joint Stock Company «Mediana-filter», Moscow, Russian Federation

<sup>2</sup> Ivanovo State Power Engineering University, Ivanovo, Russian Federation

E-mail: admin@xte.ispu.ru

### Abstract

**Background:** At the present time there is a problem to choose one of the ionic exchange organization technologies which have their own advantages and disadvantages with respect to the special conditions. There is a necessity to analyze the most widely spread technologies of countercurrent ionic exchange and to give recommendations to their implementation.

**Materials and methods:** The operation results from new water treatment facilities on some domestic and international CHPP have been used. The research of counter-current technology Schwebbett has been done under laboratory conditions. The results have been treated by methods of mathematical statistics using regressive analysis.

**Results:** Two of the most widely spread counter-current ionic exchange technologies have been analyzed, recommendations for mitigation and elimination of their main disadvantages have been given. Recommendations to application area of these technologies for treatment of natural source water on CHPP have been given. The dependency of the minimum upstream velocity from the temperature of the water has been shown for the cation exchange resin MonoPlus S100.

**Conclusions:** It is proved that while choosing the counter-current ionic exchange technology it is necessary to consider several parameters, the most important of them are the capacity of the water treatment facility and the quality of water to be treated. For systems with broadly changing capacity, for systems with big surplus capacity as well as for systems with big amount of duty technological lines the preference shall be given to the technologies similar to UPCORE. Such technologies are more preferable by refurbishment of the existing co-current ion exchange systems as well as for systems with low level of automation. The similar to Schwebbett technologies have been proven well on water treatment plant with low capacity, they can also be more economically efficient while demineralizing of water with low salinity.

**Key words:** thermal electrical plants, water treatment, ionic exchange, countercurrent ionization of water, technological improvement.

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УДК 532.542

## APPLICATION OF THERMAL HYDRAULIC DISTRIBUTOR IN SUBSTATIONS OF DISTRICT HEATING SYSTEMS

V.V. SENNIKOV<sup>1</sup>, A.A. GENVAREV<sup>1</sup>, A.M. SMIRNOV<sup>1</sup>, A.S. MAGNITSKIY<sup>1</sup>, Y.V. YAVOROVSKIY<sup>2</sup>

<sup>1</sup> Ivanovo State Power Engineering University, Ivanovo, Russian Federation

<sup>2</sup> Moscow Power Engineering University (Technical Institute), Moscow, Russian Federation

E-mail: kbispu@mail.ru

### Abstract

**Background:** Technical solutions to elimination of load influence of heat water supply and ventilation on the water consumption during the heating as well as changing the water consumption on parts of heating networks and on the heat resources at present time while heating networks are operated do not exist. To eliminate load influence of heat water supply it is suggested to use thermal hydraulic distributor in substations of district heating systems.

**Materials and Methods:** The experiments were carried out to confirm the accuracy of calculations of the mathematical model of thermal-hydraulic valve and pump unit mixing with frequency-controlled drive.

**Results:** A mathematical model of thermal-hydraulic valve and pump unit mixing with frequency-controlled drive is described. It is shown that the installation of thermal-hydraulic valve provides the required temperature and humidity conditions of consumers' premises, a constant cost of water mains and water heating system at different ratios of the maximum flow rate for hot water provides by using thermal-hydraulic valve. According to results of the calculations the graph of the delivery water flow and water heating in the changing water flow to the DHW was constructed.

**Conclusions:** The results can be used in individual heating plants or central points of thermal district heating system to eliminate the effect of the DHW variable load on modes of heating and ventilation heat consumers, constant flow of delivery water is provided by using this setting.

**Key words:** thermal-hydraulic distributor, individual heating plant.

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# ELECTRICAL POWER ENGINEERING

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## ELECTROMAGNETIC FIELD OF END AREAS OF LENGTHY CONDUCTORS AND PIPELINES

V.K. SLYSHALOV<sup>1</sup>, Yu.V. KANDALOV<sup>2</sup>

<sup>1</sup> Ivanovo State Power Engineering University, Ivanovo, Russian Federation

<sup>2</sup>JSC Branch «UES» Ivanovo RDU, Ivanovo, Russian Federation

E-mail: kandalov@ivrdu.so-ups.ru

### Abstract

**Background:** The problem of the electromagnetic field calculation in the end areas of lengthy objects, built in the conductive earth, which is a specific area where a cylindrical wave spreads along the object and becomes a spherical wave moving in free space, is urgent in science because of the lack of studying. The currency of the such calculation is defined by means of the fact, that the field in the end area defines the object's load features and allows to finish the mathematical model of object functioning in whole.

**Materials and Methods:** Electromagnetic field calculation is provided on the basis of the Helmholtz's equation for spherical area.

**Results:** Electromagnetic field calculation is made on the basis of the Helmholtz's equation for spherical area. The integral parameter  $z_2$  is found. It helps to lock the task about the field and features of pipelines and to insert the equations with distributed parameters in calculation practice.

**Conclusions:** The received results let us eliminate the volume of the calculating part of integral parameter solution to input resistance of the pipeline end area of final length as well as consider the pulse conditions in pipelines with the influence of lightning discharges and other nonsinusoidal unperiodical currents and voltages.

**Key words:** grounding conductor, pipeline, electromagnetic field, cylindrical wave, spherical wave, wave equation.

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УДК 621.311

## STABILITY OF ELECTRICAL POWER ENGINEERING SYSTEM CONSISTING OF TWO ELECTRICAL POWER STATIONS WITH CONTROLLED SERIES COMPENSATION

V.P. GOLOV, A.A. MARTIROSYAN, I.A. MOSKVIN, A.A. VINOGRADOVA  
Ivanovo State Power Engineering University, Ivanovo, Russian Federation  
E-mail: golov@ispu.ru

### Abstract

**Background:** One of the directions of developing managed interconnections is the application of the regulated devices of series capacity. The research of their impact on electrical power system modes and the choice of optimal control parameters are the urgent tasks for their practical usage.

**Materials and methods:** To find solution to this problem the completed mathematical model of such a system has been designed subject to electromagnetic transients existence in stator circuits and transmission line elements.

**Results:** The article considers the controlled series capacitors impact on modes and stability of the electrical power system consisting of two electric power stations.

**Conclusions:** The findings can be used in construction of power transmission lines with controlled elements, dynamic and steady-state stability calculations, creation of controlled series capacitors operating systems. Controlled series capacitors allow to increase power transmission line capacity, improve dynamic and steady-state stability that leads to reliability and efficiency growth of power systems operation.

**Key words:** Controlled series capacitors, electrical power system stability, power transmission line capacity, mathematical model.

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# ELECTROMECHANICS

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УДК 621.7.06

## RESEARCH OF INFLUENCE OF SURFACE ROUGHNESS OF WORKING GAP WHILE FRICTION OF MAGNETO-LIQUID DEVICE

V.A. POLETAEV, T.A. PAKHOLKOVA, S.M. PERMINOV  
Ivanovo State Power Engineering University, Ivanovo, Russian Federation  
E-mail: poletaev@tam.ispu.ru

### Abstract

**Background:** Nowadays the problems of roughness influence of magneto-conducted surfaces on magnetic field redistribution in the working gaps of electromechanical devices filled with fine-dispersed magnetic medium are not studied and urgent for the research.

**Materials and Methods:** The research was carried out on the special experimental unit which allows to use bushes and magnets made from different materials. The surfaces of the changeable magnetically conductive shaft bushes are treated in different technological modes to get different values of their roughness. The surfaces are researched with a profilograph.

**Results:** Surface contours and roughness parameters of bushes surface are defined. The experimental dependence of friction moments of magneto-liquid device from shaft rotation speed with the bushes having different surfaces roughness is discussed. It is demonstrated how the roughness of details surfaces of working gaps influences the friction moment of a magneto-liquid device.

**Conclusions:** It is proved that the growth of surface roughness of magnetically conductive details connected with the magnetic liquid in magnetic field can cause the increasing of the exchange forces between magnetic liquid and details surface. This factor allows to decrease the power engineering losses in magneto-liquid devices as well as to increase the given moments thought magnetic liquid.

**Key words:** surface roughness, magnetic field, fine magnetic media.

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УДК 621.538

## RESEARCH OF END MAGNETO-LIQUID SEALER BY MATHEMATICAL SIMULATION METHOD

S.M. PERMINOV  
Ivanovo State Power Engineering University, Ivanovo, Russian Federation  
E-mail: mizonov@home.ivanovo.ru

### Abstract

**Background:** The technical characteristics of the end magneto-liquid sealers with a number of distinctive features of the widely used dock with radial clearance as well as their operation have not been studied a lot.

**Materials and Methods:** Technical characteristics of magneto-liquid sealer are determined based on the results of modeling. To determine the distribution pattern of the magnetic field and its parameters the method of mathematical modeling of the magnetic field of the magnetic system based on the finite element method is used.

**Results:** It is determined that the magneto-liquid sealers are significantly different from medium and induction magnetomotive force in the gaps and under opposite pole attachments. The smaller the diameter of the shaft is, the higher the mean difference and magnetomotive forces inductions under opposite pole attachments. In the end sealers the magnetic forces of attraction between the magnet system and the shaft are significant and directed along the axis of the shaft, they are not balanced, as in Fluid Dynamics with a radial clearance, and fully support with the bearings that increase the moment of friction and wear of bearings. The dependences of the magnetic forces of attraction and the maximum differential pressure of the retained value of the adjustable working gap are defined.

**Conclusions:** These results allow a science-based design the magnetic end seals.

**Key words:** magnetic end seals, magnetic force, maximum withholding drop of pressure, adjustable working gap.



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## QUALITY INCREASING OF MAGNETIC TUMBLING IN MAGNETOABRASIVE DEVICE

V.A. POLETAYEV<sup>1</sup>, L.K. CHERNOV<sup>1</sup>, T.YU. STEPANOVA<sup>2</sup>

<sup>1</sup> Ivanovo State Power Engineering University, Ivanovo, Russian Federation

<sup>2</sup> Ivanovo State University of Chemistry and Technology, Ivanovo, Russian Federation

E-mail: poletaev@tam.ispu.ru

### Abstract

**Background:** The existing structures of magnetoabrasive devices do not allow to be reconstructed by changing the arrangement of permanent magnets on the rotating disk and the housing and their quantity. It is required to develop new designs of such devices and to study the parts polishing process to increase their quality.

**Materials and methods:** When the parts are being polished, magnetic fields produced by permanent magnets of different shapes and different materials are used as well as cutting/cooling media of different compositions.

**Results:** It is considered the general structure of the plant and the principle of magnetic tumbling details. The results of the finishing machining of details made from the nonferrous metals with twenty-two permanent magnets on the rotating disk and the housing of magnetoabrasive devices are given. It is proved that metal removal and surface roughness quantity depend on the arrangement of permanent magnets on the rotating disk and the housing of magnetoabrasive devices and their rotation in relation to each other.

**Conclusions:** The presented method of finishing machining of nonferrous metals can significantly increase the quality of their surfaces.

**Key words:** tumbling, magnetic tumbling, particle of filler, a permanent magnet.

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# METHODS OF MATHEMATICAL SIMULATION

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УДК 004.896

## ON IMPROVING NEURAL NETWORK TRAINING PROCESS WITH PRE-TRAINED FRAGMENTS

I.F. YASINSKIY

Ivanovo State Power Engineering University, Ivanovo, Russian Federation  
E-mail: igor2266@yandex.ru

### Abstract

**Background:** For many applications, including power engineering branch, the duration of neural network training can be an obstacle, preventing its usage.

**Materials and methods:** The method of opposite error propagation is used for neural network training.

**Results:** A new principle of the neural network structure is suggested and researched. The architecture is formed by the pre-trained neural network fragments-professionals.

**Conclusions:** The described architecture allows to accelerate the neural network training and improve its quality of work. A promising direction in the development of neural network can be the creation and accumulation of the database of trained neural networks, that solve a variety of application tasks, including the energetic processes automation.

**Key words:** neural network technologies, neural network architecture, training algorithm.

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УДК 621

## EFFECTIVE USAGE OF HETEROGENEOUS COMPUTING SYSTEMS

L.P. CHERNYSHEVA, D.P. HARITONOV

Ivanovo State Power Engineering University, Ivanovo, Russian Federation  
E-mail: chernlu@vvs.ispu.ru

### Abstract

**Background:** In heterogeneous systems a sophisticated way of organizing a parallel computing system is used, they combined multi-core processors and graphics cards. The important issue of efficient use of computing systems with a complex architecture is currently poorly researched.

**Materials and methods:** The systems of ordinary differential equations in various large-scale parallel programming technologies are being solved. Acceleration of calculations is determined by using the law of Amdal.

**Results:** Numerical experiments are carried out to find the ways of efficient use of a heterogeneous system.

**Conclusion:** The results of numeric experiments show that the combination of different parallel programming, taking into account the characteristics of the system architecture, is a means of improving efficiency of the heterogeneous system.

**Key words:** heterogeneous system, calculations efficiency, methods for the solution of ordinary differential equations of large dimension.

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УДК 004.8

## THERMODYNAMIC FORMALISM FOR RESEARCH AND CONSTRUCTION OF ALGORITHMS AND NEURAL NETWORKS

I.F. YASINSKIY, F.N. YASINSKIY  
Ivanovo State Power Engineering University, Ivanovo, Russian Federation  
E-mail: igor2266@yandex.ru

### Abstract

**Background:** A.Kolmogorov introduced the concept of computational entropy. After that a number of researches appeared (Tihomirov V.M, Vitushkin A.G., Petri N.V.), where the entropy was effectively used for the complexity evaluation of algorithms and programs.

**Materials and methods:** Ideas and methods of phenomenological and statistic thermodynamics are used to estimate the amount of calculations or volume of the neural network.

**Results:** Introduction of the other thermodynamic functions, besides entropy, and the definition of the three thermodynamic origins in the context of calculations allows to study stability, organize the parameters according their information weights, carry out the decomposition of the complex systems, construct the rapid algorithms.

**Conclusion:** Thermodynamic formalism opens up new possibilities in building of the optimal algorithms for modeling of the complex dynamic systems and construction of the effective neural networks that will find certain application in power engineering.

**Key words:** computational entropy, rapid algorithms, thermodynamics of calculations.

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УДК 004.94

## COMPUTER SIMULATION OF AIR FLOWS IN URBAN AREAS USING NVIDIA CUDA

A.L. ARKHIPOV  
Ivanovo State Power Engineering University, Ivanovo, Russian Federation  
E-mail: AIARMail999@mail.ru

### Abstract

**Background:** Modelling air movement in urban areas is an important problem, which allows determining the air flows depending on the location of city buildings. Such kind of problems is usually solved by mesh based methods on the multiprocessor supercomputer that allows performing calculations with great efficiency. However, this approach requires expensive computer hardware. In this article the usage of the GPU as a computational device instead of expensive multiprocessor computer is suggested. Nowadays, two main market players of graphic processors, NVIDIA CUDA and AMD, suggest the technologies of GPU usage for general purposes calculations. The more developing technology of general purposes calculations on GPU is NVIDIA CUDA platform.

**Materials and methods:** NVIDIA CUDA is used to calculate on the graphic processors. This choice was made on the basis of API and support of the most widely-spread NVIDIA GeForce video-cards. The finite-difference calculation scheme is adapted for using the graphic processors as a calculation means.

**Results:** In this article a way to solve a problem of the modeling the movement of air in urban areas is proposed. The GPU is used as a computational device instead of expensive multiprocessor computer.

**Conclusions:** The finite-difference scheme and the algorithm based on it allowed to get the velocity growth of calculation due to their implementation on the NVIDIA CUDA platform comparing to the algorithm which works with the central processor. As a result, the outstanding calculation velocity growth is received. The usage of graphic processors as a calculation means and algorithm adaptation allows to decrease the cost of computer equipment which is necessary for calculating, for solving the tasks of the movement modelling of air in urban areas up to 60–70 times.

**Key words:** numerical simulation, differential equations, Navier–Stokes equations, parallel computing, NVIDIA CUDA.

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# COMPUTER SCIENCE AND INFORMATION TECHNOLOGIES

УДК 004.6

## CREATION AND INTERNET PUBLISHING OF ZONING MAPS OF REGIONAL POWER SUPPLY SYSTEMS

S.V. KOSYAKOV, E.R. PANTELEEV, A. M. SADYKOV  
Ivanovo State Power Engineering University, Ivanovo, Russian Federation  
E-mail: ksv@ispu.ru

### Abstract

**Background:** One of the tasks of the state policy in power engineering is to provide local authorities, energy consuming organizations and investors with information that coordinates plan of fuel and energy balance complex development with other regional infrastructure objects development plans. Data concerning power engineering objects, such as installed capacity, power reserve and development plans is now easily available via Internet sites of regional power companies. However, this data is fragmented which hampers the holistic pattern of regional power supply structure. Subject map is considered to be the most evidential and informative presentation of spatial structure of regional power supply structures. Meanwhile the creation and publication of such maps takes time and personnel and costs money.

**Materials and methods:** The method that includes the integration and aggregation processes of the data about quarterly dividing of the territory as well as attributive data about the power engineering units is used. The data is received from free sources. The implementation program is provided on the basis of 'cloudy' ArcGIS Online geoinformation system.

**Results:** The method of zoning maps automated building and publishing in relation of belonging the territory to different energy sources (electric substations or their feeders, boiler houses, heat power stations) is provided. On the basis of method proposed, an experimental internet site is developed where spatial structure of regional power supply structures of Ivanovo town is published. It shows local power suppliers capacity distribution among consumers, detects power reserve hence gives a key to further development of consumers' net. Informational background is the open data which published by local energy providers.

**Conclusion:** The proposed method can be used in decision support systems considering the problems of investment planning and management of regional power systems development.

**Key words:** spatial analysis, zoning, power systems, GIS.

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УДК 004.6

## INFORMATIONAL AND ANALYTIC SUPPORT OF POWER ENGINEERING POLICY AT REGIONAL LEVEL

I.D. RATMANOVA  
Ivanovo State Power Engineering University, Ivanovo, Russian Federation  
E-mail: idr@osi.ispu.ru

### Abstract

**Background:** The structural changes in power engineering which take place in Russia have sharpened the situation and increased interest to regional power engineering problems. Taking into account regional heat-and-power network (HPN) complexity, intersection of numerous departments' interests, combination of several dozens of economic activity types, hierarchical geographically dispersed structure, effective HPN management becomes an obviously complex problem. Besides, reasonable power engineering policy is impossible without relevant informational support.

**Materials and methods:** The main components of regional power engineering policy informational and analytic support were designed on the basis of detailed legal framework research.

**Results:** The informational decision making support technology for regional power economy making policy based on informational and analytic system of heat and power balancing is developed.

**Conclusions:** The obtained results can be applied to enhance power economy efficiency in the region.

**Key words:** regional power engineering policy, energy-saving, decision making information support, information and analytic system.

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УДК 681.5

## DEVELOPMENT OF METHODS FOR INCREASING EFFECTIVENESS OF CLIP CONNECTIONS IN DESIGNING INSTALLATION ELEMENT OF AUTOMATION SYSTEMS

A.V. GLYAZNETSOVA, E.S. TSELISHCHEV  
Ivanovo State Power Engineering University, Ivanovo, Russian Federation  
E-mail: glyaznetsova@mail.ru, etselishhev@rambler.ru

#### Abstract

**Background:** The existing methods for creating clip connections, which are used in different CAD-systems (Promis-e, E-Plan, AutoCAD Electrical, etc.), do not allow to get a high degree of automation or even approach to it. It is necessary to develop new methods, which can increase the effectiveness of forming clip connections. It allows to decrease the working hours, exclude the accidental mistakes, cut down the design period of installation elements of automation systems, increase the quality of designed documentations, cut down the expenses during installation, setup and system operation.

**Materials and methods:** The set theory, aggregative and decomposed technology of multicomponent electrotechnical systems (particularly, the synthesis method of technical structures while designing installation elements, based on united project model as an information resource for any designing procedure) are used for increasing the effectiveness of forming clip connections. The research of the existing ways of forming clip connection is carried out on the basis of the analysis of different systems of the computer-aided design.

**Results:** The new methods of forming connecting boxes and terminal blocks where the additional operations of terminal blocks treatment (adding the reserve terminals, cable screen connection, saw setting of loop, etc.) are taken into account, are developed. These methods are used in CAE AutomatiCS and approved in different design engineering organizations for the purpose of clip connection automated design.

**Conclusions:** The developed methods are applied in CAE AutomatiCS for designing the installation elements of automation systems. These methods allow to achieve a high degree (about 90%) of automation while designing clip connections, that is unachievable in traditional designing technologies, applied in the mentioned systems.

**Key words:** clip connections, element, connection, clip (terminal), functional element, transit element, designing automation.

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# ECONOMICS

УДК 620.9

## ANALYSIS OF INTERNATIONAL BACKGROUND IN CERTIFICATION OF PROFESSIONAL QUALIFICATIONS IN POWER ENGINEERING

V.V. TYUTIKOV, E.O. GRUBOV, U.F. BITERYAKOV  
Ivanovo State Power Engineering University named, Ivanovo, Russian Federation  
E-mail: tv@ispu.ru, egrubov@economic.ispu.ru

### Abstract

**Background:** The development of professional qualification programs certification in different countries is a reaction to dynamic changes in the labor market. Creation of qualification certification mechanisms for specialists and educational institution graduates is presumed in the Russian Federation at the present time with consideration of educational and professional standards integration.

**Materials and methods:** The content analysis of the available sources including international professional associations websites was carried out, methods of information comparison, matching and integration were applied.

**Results:** The comparative analysis of background in creation of professional qualification certification systems in power engineering, certification procedures, applied methods, models and measurements, consumers of qualification certification results, certification systems and their stakeholders interaction processes was performed.

**Conclusions:** Analysis of international background in certification of professional qualifications in power engineering allows to reveal specific features to be considered in creation of the national system of assessment and certification of professional qualifications in the Russian Federation.

**Key words:** certification of qualifications, licensing, educational standard, professional standard, certificate, educational program, accreditation, engineering profession, European engineer, power engineering.

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УДК 303.732.4

## APPLYING SPECIALIZED GRAPH-SCHEME FOR DESCRIBING VARIANTS OF ENERGY SAVING ACTIONS

V.S. MOKROUSOV  
Vladimir State University, Vladimir, Russian Federation  
E-mail: valmok@mail.ru

### Abstract

**Background:** The problem of selecting actual and effective energy efficiency measures has become very important due to the increased requirements to perform energy audits. The problem of visualizing the list of measures can be solved by developing specialized graph-scheme of heat supply system.

**Materials and methods:** The development of graph-scheme is made on the basis of methods of mathematical logic and graph theory.

**Results:** The structure model for the description of energy conservation measures in a visual form was developed. As a result of energy audit of industrial enterprises is made up a specialized section of the graph-scheme of the heating system. A general form of the graph-scheme of heat supply system of the industrial enterprise was developed/

**Conclusions:** The obtained results can be applied to improving the quality of the choice of cost-effective energy conservation measures.

**Key words:** graph-scheme, energy conservation measures, heating system of an industrial enterprise.

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