Complex Problems of Power Systems Based on Renewable Energy

Ludanov K., Bratanich T. (Kyiv). Hydrogen accumulation. The kinetics of hydrogen absorption in metals.

The paper developed analytical methods for calculating the parameters of the exponential curve of the kinetics of hydrogen absorption of metals on the basis of a small sample of experimental data: a brief derivation of the process and developed methods of co-determination of integral parameters of the hydrogen absorption - the maximum specific hydrogen capacity, reduced diffusion resistance of uptake of H_2 and "activation time" surface. This method is implemented by solving systems of two transcendental equations as coefficients which are used by the experimental data of hydrogen absorption.

Paragraph 1 of "findings" based on the integration of the first Fick's law in differential form held a brief derivation of mathematical expressions absorption kinetics hydrogen yes in metals. Formed integral parameters of exponential curve kinetics: diffusion resistance RD, the maximum hydrogen capacity Hmax and induction period tA surface activation.

Paragraph 2 of "findings" presented the joint determination of the two parameters, RD and Hmax exponential curve kinetics of hydrogen absorption of metals by solving a system of two transcendental equations obtained on the basis of limited sample of experimental data. In conclusion, are two examples of determining the parameters of the exponential curve of the kinetics of a small sample of the experimental data of the absorption of hydrogen composite 50TiFe – 50Ni at different temperatures (303 K and 343 K).

Paragraph 3 of "findings" presented the joint determination of the two parameters, RD and tA exponential curve kinetics of hydrogen absorption of metals by solving a system of two transcendental equations obtained on the basis of limited sample of experimental data. Finally, an example of determining the parameters of the exponential curve of the kinetics of a small sample of experimental data hydrogen absorption intermetallide Ti_2Ni.

Paragraph 4 represented the conclusion of the mathematical expression of the activation energy of QA process of diffusion of hydrogen in metals and an example of calculating values of the formula QA for composite 50TiFe – 50Ni.

M. Kuznietsov. (Kyiv). Modeling common work for wind and solar power plants.

Wind and solar power have a random nature, since they depend on the weather. It is reasonable to develop mathematical models of current wind and solar power, to assess the possibility of certain operating modes with a given confidence level. Particular attention should be paid to local energy systems (especially self-contained) where limited opportunity to compensate for the lack or surplus of working capacity.

Mathematical model of wind power was considered in previous works. Representing as averaged values for a given season (trend line), average daily value as a random variable and short-term changes as a random process were applied, taking into account data from different time averaging – monthly, daily, current (at intervals of a few minutes). A similar approach is applied to the simulation of solar radiation. You need to determine the probability distribution of random fluctuations in solar radiation caused cloudy. Previously, it was found that a certain level of consistency days of cloud during the year is similar to discrete Markov chain. It is assumed that the level of solar radiation at certain hours of the day are independent random variables. Data on the level of solar radiation in Kyiv region for several years was used to confirm the assumptions. Autocorrelation analysis shows that hourly averaged solar radiation also resembles a Markov process and current deviations are independent. Thus, one can allocate the average daily random component and current fluctuations, which are stochastic in nature.

The mathematical model was proposed takes into account the average values, dispersions, allowable change per unit of time, the distribution of the probability of certain values. Data from different time averaging was used, similar to the patterns of wind energy. This allows us to simulate a joint capacity of wind and solar power, for example using the Monte Carlo method, and determine the probable distribution of the total capacity. Adequate modeling of solar radiation was tested on the example of actual weather information. It was established also a weak correlation dependence of wind and solar energy. The specific nature of such dependencies can be studied by analyzing a significant amount of synchronous records of wind speed and solar radiation with the least possible time step, and the results of the study will relate only to a particular climate zone.

Nakashidze L., Gabrinets V., Trofimenko A. (Dnipropetrovsk). Factors affecting the heat balance facilities with the use of alternative energy sources.

In the design, construction and operation of buildings of residential, recreational, industrial use it is necessary to provide a cost-effective use of heat and electricity. Planning and implementation of measures for the creation of energy-saving power supply systems are impossible without mathematical modeling of energy processes in buildings.

All elements of the power supply system of the building are interconnected. When creating structures for energy supply which spent a minimum amount of energy (coal, gas, etc.) there must be considered a complex engineering structures and engineering systems.

For effective reduce of energy consumption it is proposed to use the building fences, which not only prevent heat loss from the building, but also are an active part of the energy supply system. The proposed energyactive fences are multifunctional, i.e. they transform alternative energy sources (solar energy, environmental heat, heat vent discharges), facilitate regulation and redistribution of heat fluxes.

It is possible to display objectively the heat and mass transfer processes occurring in the application of energy active in the construction of fences with physical and mathematical models that characterize the thermal regime of the building.

It is proposed to conduct a multi-level detail design schemes of the energy regime of the building. The degree of detail is determined by features of heat and mass transfer processes that occur during the operation of the reporting buildings.

It is recognized that the design features of the energy active fences lead to changes in the physical and technical characteristics of fencing structures

In the mathematical description of the thermal balance structures there must be reflected the fact that the availability of energy active fences causes heat flow which is directed from inside the outer layer of the structure. Availability of energy active fence can significantly reduce heat transfer coefficient of building envelopes (up to 1-1.3 W / m^2 K). The heat is redirected to the power supply system with the help of the heat exchangers and special channels in the energy active fences and protective structures provided in this system. Fresh air can be heated by the heat of extract air. The mathematical model of the process should reflect the thermal balance of both flows and intensity of their circulation.

When drawing up the heat balance of buildings it is necessary to consider that using energy active fences may organize specific normative heat consumption up to 45 W/m^2.

In preparing of the heat balance of buildings there can be provided different operation modes of the energy supply system, such as the constant, periodic, mixed.

Thus, detailing of all factors, that emerge when using energy active fences, even in the preparation of the heat balance of structures, i.e. inventory of possible heat gain and heat loss leads to economy of the organic fuel (coal gas).

Solar Energy

Gaevsky A., Ushkalenko O. (Kyiv). Determining optimal angles of photovoltaic panels.

PV plant effectiveness depends on load profiles and sum of radiation, PV plant equipment characteristics and its construction. For PV plants with fixed PV modules it is important to define tilt angle and orientation of the solar panels that lead to maximum power production. Condition of maximum of global radiation for cyclic period of time is widely used for optimal value of tilt angle and orientation definition. In the current article analytical method of optimal panels tilt angle definition is developed. This method takes into account direct, reflected and diffuse components of radiation. Values of these components may be taken from meteorological sources or from models. Using analytical expressions from current article, which does not need huge calculations, gives the opportunity to find optimal values of panels tilt angles for any geographical location and working period. Also in this article examples of tilt angles calculation using two data sources: USSR climate reference book and NASA data base, can be found.

Gamarko A. (Kyiv). Methods of numerical approximations of current-voltage curves of a photovoltaic module.

The paper considers the existing mathematical models of PV modules (PVM) and proposes using linear approximation to create a mathematical model for a PVM.

There have been considered several approximation methods. Existing current-voltage characteristic for PVM HIT Power 200S have been used as input data.

The first method is a method of piecewise linear interpolation. According to this method adjacent points should be connected by straight segments thus resulting a broken line and the last should approximate our curve. A separate own function $g_k(x)$ is being built for each segment. The functions $g_k(x)$ for each segment out of n [xk, xk + 1] are being the first degree polynomials and they can be obtained from the line equation that passes through (xk, yk) and (xk + 1, yk + 1).

The second method is a method of cubic splines. According to this method adjacent points should be connected by piecewise cubic polynomials with the following parameters: twice continuously differentiated; each partial segment of a cubic polynomial looks as follows:

$$S_i(x) = a_i + b_i(x - x_i) + c_i(x - x_i)^2 + d_i(x - x_i)^3,$$
$$x \in [x_i, x_{i+1}];\ i = 1, 2, ..., n - 1.$$

There has been written a computer program on the basis of these two methods. It performs simulation of PVM current-voltage characteristics. Apart the above these two methods have been analyzed and the findings have been presented in the article.

Bondarenko D. (Kyiv). Smart digital photovoltaic systems.

Using renewable energy sources in different electronic systems goes to development photovoltaic systems to "smart" realization. In article, shown possible mode of operate (maximum load, maximum save charge, combining load and saving charge in accumulator, emergency mode, etc.) and described different variations of build these systems. For build smart system, proposed using of microcontrollers with analog-to-digital converters for dig-

itization of current and voltage value inside PV-battery and accumulator, and proposed using of communication interfaces for connection between devices. For loads, was proposed of using inside controllers for management of consumption. In this system, main controller has to manage supply and consumption by using commands of direct management in load. Also, for simplification of wiring and universalism, proposed combination power line and communication line to two-wire line. Selected general chipset for building of this system and outlined possible communication protocol.

Wind Energy

Golovko V., Kokhanevych V., Shykhailov M., Budko V. (Kyiv). The influence of rotor orientation parameters of the constructive scheme "tail oblique hinge" over static characteristics of wind turbines.

One of the criteria to evaluate small wind turbines efficiency is minimizing operation losses that are defined by their components. Rotor orientation system is one of such components. The rotor orientation system using directional plane with rotor removal from the wind and a constructive scheme "tail oblique hinge" belongs to one the most used rotor orientation systems.

The paper suggests considering the above-mentioned rotor orientation system, namely developing a mathematical model of such orientation system and obtaining on its basis static characteristics and power curves based on the design parameters thus making it possible to analyze the impact of design parameters on energy losses.

On the basis of a mathematical model there were defined the parameters determining the static characteristic of regulation system and the power curve. These parameters are as follows:

- Weight of the tail;
- The distance from the axis of tail rotation to the center of tail mass in a plane perpendicular to the axis of tail rotation;
- The angle of inclination of tail rotation axis to the axis of rotor rotation;
- The amount of rotor axis displacement regarding nacelle rotation axis;
- The tail installation angle relatively to the air stream;
- The angle between the arm and the tail rotor shaft.
- The analysis results of the static characteristics and power curves lead to the following conclusions:
- The system can distinguish a group of orientation parameters, whose influence on the static characteristics and power curves leads to changes in the initial velocity adjustment (increase or decrease) and the value of maximum power in accordance with a shift in the direction of their wind speed increase (or decrease). These are: the mass of the tail, the distance from the rotational axis to the center of the tail mass in a plane perpendicular to the axis of tail rotation over tail inclination angle to rotor axis rotation;
- The influence of the tail installation angle relatively to the air flow is negligible;
- The value of the rotor axis offset against the axis of head rotation should be taken at the range of $\varepsilon_\Gamma \geq 0{,}2$ m for wind turbines with a rotor diameter 6 m in order to reduce the influence of frontal pressure center displacement over the rotor;
- The angle change between the tail arm and rotor axes changes the angles of power curve inclination in the zone to the maximum power point thus allowing adapting the wind turbine to various average yearly wind speeds.

Hydroenergy

Ibragimova M. (Kyiv). Determining design parameters for small hydro power plant when controlling the power by watercourse.

Special position in long-term energy policy is devoted to renewable energies. The current EU's trends in small hydropower development are represented in the "Guiding Principles on Sustainable Hydropower Development", adopted by the Standing Working Group of the International Commission for the Protection of Danube River (ICPDR). The aim of the above-mentioned document is to get the right balance between economic and ecological needs and to minimize environmental impacts of existing and future hydropower projects.

The guidelines on use of hydropower resources, which provide an environmentally safe operation of a SHPP (small hydropower plant) without changing the hydrological regime of the watercourse, should play a decisive role in a further development of national small hydropower. All waterworks constructions affect the hydrological regime of the river. However, as opposed to a large-scale hydropower causing significant structural changes in the hydrological regime of the flow, run-of-river installations contribute to the preservation of river biodiversity.

The interest in SHPP with capacity regulation by a water flow is renewed at the current development of small hydropower. This mode of operation of hydropower plant has almost no effect on the natural flow regime and biological conditions of the downstream watercourse.

Previous studies of capacity regulation by a water flow at SHPP have been mostly devoted to automation of regulation and control processes. Nowadays, the issue of selecting an appropriate design capacity and number of hydropower units considering the capacity regulation of small hydropower plant by the water flow and environmental limitations on water use for power production becomes relevant.

The following calculations are based on the Krytskyy-Menkel three-parameter probability distribution of water flow. The probabilistic approach has been used to define necessary parameters of hydropower plant as a function of water discharge.

The calculations were performed for variants of small hydropower station with 1, 2, 3, 4 hydroelectric units of equal capacity. The value of the design flow of a plant is proportional to a long-term mean annual flow rate of 30 m3/s and to a coefficient of the following recommended range [1.3; 1; 0.75; 0.5; 0.33]. The effective pressure head of water across the turbine is taken equal to 10 m. The weighted average coefficients of variation and skewness are equal to 0.42 and 0.82 pu, respectively (the Southern Bug river basin).

The performed studies consider assigned objectives of capacity regulation of small hydropower plant by the water flow and environmental limitations on water use for power production. The rational layout of small hydropower plant is considered a station with 3 hydroelectric units and in this case the design flow is equal to a long-term mean annual flow rate.

Geothermal Energy

Morozov Yu., Nikolayevska N., Kushnir I. (Kyiv). Geothermal heat pumps application in decentralized heating systems.

World Geothermal Congresses are held every five years since 1995. The last two congresses outlined main trends in geothermal energy development worldwide. The data comparison shows that geothermal energy use for geothermal heat pumps operation has increased from 49 to 55.3%, the use of heat in thermal water spa treatment and recreation declined from 24.9 to 20.31%. In addition direct space heating increased from 14.4 to 15.01%.

Over the past 10 years geothermal heat pumps use, namely using the upper layers of the Earth, has got the highest rates of development. "The upper layers of the Earth" is considered a conventional concept and in different sources refers to the maximum depth of 200 to 500 m.

The heat of the upper layers of the Earth can be used practically everywhere as a heat supply source using geothermal heat pumps or in air conditioning facilities. Developing technologies in the field of extracting and using the heat of the upper Earth's layers is directed to ensure environmental safety of such systems and improving its energy efficiency by applying batteries for optimal heat pumps operation.

Technically possible volumes of thermal soil energy use for heating purposes with heat pumps implementation in Ukraine are 1750 thousand t o.e. per year.

The article defines the efficiency of a heat pump use that utilizes the heat from the upper Earth layers and that uses underground heat batteries on the example of space heating in building number 2 at M.M. Hryshko National Botanical Garden, NAS of Ukraine. The heated area is about 1400 m^2. The technical characteristics have been given. There has been calculated the cost of electricity by night rate and heat storage application and the cost of heat produced by a heat pump.

The calculations have shown that night rate use in conjunction with heat storage and using a heat pump reduce the cost of generated heat by 26-30%. At the same time the specific capital investments in underground heat accumulators application are increased by 15-20%.

Sadovenko I., Inkin A. (Dnipropetrovsk). Mathematical model verification of thermal energy transfer in floodered rocks of a combusted coalseam.

The article is aimed at verifying the developed mathematical model of heat transfer in the aquifer, overlying combusted coal seam. The initial data for the solution of the inverse problem were the results obtained in carrying out the largest research project on underground coal combustion in the field Hanna in the United States. It is shown that the resulting model the dynamics of the groundwater level in the operation of modules combustion takes into account the change in the orientation of flow with increasing space, consistent with actual data for most of the period Back calculations with an absolute error of 2-6 m and an adequate reflection of the emerging in the area of the funnel of depression. The results are based on the model correspond to the actual temperature change in the reaction channel overlying the aquifer, with their relative error does not exceed 5%. These data confirm the adequacy and accuracy of the proposed model of heat transfer.

With the tested numerical model of heat transfer is possible to determine the spatial and temporal location of geothermal fields formed in the aquifer, which lies above the underground generator. The results will determine the amount of thermal energy in the flooded rock depending on geological conditions and the stage of the combustion of the coal seam, as well as its selection of technological parameters in practice.

The development model proposed by the expedient of its approbation on the real geotechnological scheme, which involves the simultaneous selection of hot water through the system from several wells. In addition, an evaluation of economic efficiency of use of thermal energy in the aquifer CSP.

Bioenergy

Kucheruk P.P. Study of kinetic parameters in the periodical anaerobic co-digestion of manure and maize silage mixtures.

The substitution of fossil fuels with renewable energy sources is a worldwide trend and actual need in Ukraine. Production and use of biogas is one of the key segments of the renewable energy market. Maize silage (MS) is one of common used raw materials for biogas production. The use of silage maize for biogas production can also be promising for Ukraine. The main preconditions for this are favourable agro-climatic conditions for growing maize in the vast majority of the territory of Ukraine as well as the availability of 2.7-4.9 million ha of free arable land equal to 8.7-15.8% of the entire arable land in the country.

It is possible to produce from 5 to 8 billion m^3 CH_4 per year from maize silage harvested on one million ha taking into account specific methane yield of 100-115 $m^3CH_4 \cdot kg^{-1}VS$ and silage yield of 50-70 $t \cdot ha^{-1}$. Effective use of this potential requires the development and implementation of efficient technologies for biogas production. Numerical simulation of technological parameters of biogas digesters involves the use of several kinetic constants of the process, the values of which could usually be defined experimentally.

Two kinetic parameters – maximum growth rate of acetoclastic methanogens, day^{-1} and the half-saturation constant, $gVS \cdot L^{-1}$ in the periodical anaerobic co-digestion of pig manure (PM) with maize silage at temperature of 36±1°C were analysed in this paper. Liquid pig manure (with dry matter content (DM) 5.67% and volatile solids (VS) 84.1% to DM) and local maize variety "Medunytsa" in wax stage of maturation (DM – 21.9%, VS – 92.1% to DM) was used for the study.

The mixtures were prepared with the initial maize silage to pig manure VS ratios of 0%, 15%, 30%, 50%, 75% and 100%. The initial concentration of the mixtures was in the range of 44.2-47.5 $gVS \cdot L^{-1}$.

Acetoclastic methanogens growth rate was evaluated based on the CH_4 yield progress curve with the further linear graphic interpretation of the integrated form of Michaelis-Menten equation. It was assumed that 70% of CH_4 yield is referred to acetate consumption by acetoclastic methanogens.

With increasing of maize silage to pig manure VS ratios from 15 to 75% the maximum methane generation rate increased from 33.2 to 171.4%, correspondingly, and this value was reached in a shorter period from process start up. With this, the mean cumulative methane generation rate increased from 27.7 to 113.2%.

The maximum growth rate of acetoclastic methanogens was evaluated at 0.114, 0.143, 0.139, 0.154, 0.1157, 0.070 day^{-1} for the mixtures with MS/PM VS ratios 0%, 15%, 30%, 50%, 75%, and 100% correspondingly. The half-saturation constant increased linearly from 31.6 to 45.6 $gVS \cdot L^{-1}$.

Budko M. (Kyiv). Studying the design parameters impact of a batch reactor over temperature mode for biomass-to-diesel energy conversion process.

The work was devoted to the study of design parameters impact on the temperature regime of periodic action reactor for biomass energy conversion into biofuel using software environment Matlab.

Based on the reacting mixture temperature change inside the overesterification reactor it was proposed to take into account reactor design parameters impact on the process flow character and suggested using stainless steel as shall material.

It has been shown that in the process of designing bioreactors intended for the production of biofuel from vegetable oils it is essential to carefully select radius of the reactor shell and material there of as factors that influence temperature of conversion process. It is recommended to preferably use reactor with natural cooling. The reacting mixture temperature excess in this case does not generate harmful effect in terms of final product yield while making reaction time shorter and reactor design simpler.