Complex Problems of Power Systems Based on Renewable Energy

KAZANSKIY S., MYHAILENKO V. **Simulation of power grid with distributed generation sources.**

The dynamic increase in the quantity and installed capacity of wind power plants (WPP) in Ukraine has been determined by implementing the state policy for promoting renewable energy development. This significant increase in total WPP capacity leads to the need for additional studies of the connection features of distributed generation sources to power grids of electric power system of Ukraine.

The main purpose of distributed generation sources integration to the electricity system is to increase the reliability of electricity supply, technical losses reduction in electricity transmission and reducing the environmental burden on the environment.

The specificity of the WPP as a distributed generation source is the need to predict the daily schedules of electric power supply, as well as other important electrical parameters such as voltage, reactive power, etc.

The article presents the results of the simulation modes for power grid with distributed generation sources, which are considered as two wind farms. A model containing a source of distributed generation with the step-up transformers as well as electric power grid with transmission lines and loads. Also results of the simulation have been analyzed. It is noted that the modelling in general adequately reflects the peculiarities of the considered grid and allows the performing an assessment of its work modes, taking into account existing standards for quality and reliability of electricity supply.

NESTERKO A. **Approach to frequency control improve-ment for a power system based on renewables.**

According to the adopted "Energy Strategy of Ukraine till 2030", market provides for widespread adoption of renewable energy sources (RES) in the power system (EPS), which cause a change in the structure of generating capacities of the united energy system (UES) of Ukraine, its frequency and operating conditions mode of existing automatic control systems.

Wide area monitoring system (WAMS) data analysis opens new possibilities to identify and refine models of electric power systems, which can be used for frequency transients optimal controller synthesis.

Resent researches have shown possibility of appearance of coherent groups of generators (CGG) allows to reduce the complexity of EPS dynamic model to appreciate the main electromechanical transients only. Besides that, assumption of CGG invariance to imbalance location and type is accepted.

Difficulties of unit RES generation prediction can overcome using virtual power plants (VPP) concept that combines aggregation and territorial dispersion of renewables. Besides that, resent researches show that inverter connected types of RES can control their output power on sub second time intervals. Together, VPP concept and controllable RES form operational reserves for centralized load-frequency control system.

This work propose the approaches to the use of controlled renewable energy sources in the load frequency control system; structure and algorithms of the hierarchical system of EPS frequency centralized control.

Due to necessity of safety and efficiency of control, it was proposed to use model predictive optimal control strategy. Linearized model of UES of Ukraine was used to synthesize controller that can consider regulation constraints. Main regulation constraints that was taken includes available VPP operational reserves and their loading/unloading dynamics.

The results of transients calculation of three phase short circuits of 750kV bus on Zakhidnoukrainska, Donbaska and Kievska power substations showed that damping of low frequency oscillations during frequency transients had been increased in three times while using proposed control strategy. Besides that, all controller actions considered only available power reserves during frequency control.

Solar Energy

SURZHYK T. **Studying polymeric composite absorber for solar collectors.**

There was created a solar collector (SC) absorber and it was made of polymeric composite material based on carbon fibre with fillers. The required thermal and strength properties of the material were achieved due to carbon fiber fillers and related production technologies.

Implementing radiation technologies for polymer composition hardening resulted in obtaining materials with improved physicochemical properties and high weather resistance. Compared to the thermochemical method the radiation hardening method has got the following advantages: high hardening speed; polyester binders harden without introducing initiators and peroxide compounds; higher strength levels.

KOLOMIETS D., KHARCHENKO L., MATYACH S. **Defining average temperature of photovoltaic panels**.

There have been performed research studies aiming to determine options for effective solar batteries use when using them as the source of direct current and thermal energy simultaneously. The studies were performed at 2 solar batteries START BS-1 type at Kyiv city. They also determined the performance efficiency of both options.

It was determined that in summer, even at unfavourable weather conditions (large cloudiness) and during non-optimal (vertical) solar batteries orientation, the temperature of internal PV surface of photo cells can reach 60ºC and higher. The temperature measurement results showed that even in the shadowed place the PV surface is 5 to 6 degrees higher that standard temperature.

Cooling solar batteries does increase their electric efficiency and can also be the source of large thermal energy amount. PV's heat output is possible to calculate if the information on changes in time-averaged temperature of their surfaces is available. This information is gained experimentally or analytically.

The suggested method of analytical calculating average temperature of the battery is based on divergence theorem for equation of non-stationary heat conduction with volumetric heat generation.

The full-scale experimental studies resulted in findings that theoretical analysis and experimental data are in good match. The data obtained are relevant to determine optimal geometric dimensions and parameters of a solar PV module with heat-removing devices. The data is also important to

determine heat conductivity ratio for composite material of the heat-removing panel.

KHAIRNASOV S. **Heat pipes application in solar energy systems: concentrating solar systems, solar wall, solar cookers.**

Environmental problems such as global warming and environmental pollution require the use of alternative energy sources both for energy supply of buildings and in transport and industry. These problems will raise energy prices until renewable energy sources replace conventional fuels as the basic source. The global need for energy savings and necessity in renewable energy sources use today develops new approaches and methods of energy producing and conversion. Today much modern heat-exchange equipment does not meet the requirements of low weight, easy installation, versatility, scalability and autonomy. Setting the task of passive heat and mass transfer systems creating makes clear that usage of heat pipes offers great opportunities to solve problems in new energy efficient solutions. Heat pipes technology is known for rather long time. They have excellent heat transfer properties, high efficiency and often have simple construction. In addition, they are completely autonomous system and have no mechanical moving parts. There are various constructions using heat pipes as energy saving systems as well as elements of systems that function using renewable energy sources. But above all heat pipes have a good prospect as an application in solar energy systems. Solar energy is one of the most promising energy sources and can be considered as a step towards reducing dependence on other energy resources. Using heat pipes in solar power systems has been considered since the 80s. Today industrial production of heat pipes and evacuated and flat plate solar collector on their basis is already available. Heat pipes used in the evacuated and flat plate solar collectors allow simplifying assembly procedure, high modularity, maintainability, and reliability. However other types of solar energy equipments are perspective today. Photovoltaic and thermoelectric power systems with the concentration of solar energy, solar wall, and solar cookers can widely use heat pipes. The article provides an analysis of the current state of heat pipes application in such solar energy systems.

Wind Energy

GOLOVKO V., KOKHANEVYCH V., SHYKHAILOV M., ZINCHENKO T., SANDOVAL Z. **Analysis layout of autonomous wind power systems with asynchronous generators.**

The article analyzed structural schemes of autonomous wind power systems with asynchronous generators. It has been determined the dependency of a consumer's electricity supply channel load on the degree of its bandwidth.

An autonomous wind power system generally consists of a wind turbine, excitation control unit, power batteries with a control charger, inverting equipment and the block to synchronize system output parameters to consumer needs. Depending on their layout there can created block diagrams that work separately or together for consumer needs.

In terms of energy saving the circuit with least units' number has got the least losses. It can be used for consumers who do not impose stringent technological requirements for future energy supply. In this case power supply reliability depends on the probability indicators for wind energy intake values of wind turbines' working speed.

The scheme with accumulating and inverting equipment reduces energy supply dependence over fluctuations from wind energy over time. This scheme demands coordinating energy units, namely the amount of supplied energy, the amount of accumulated energy and the amount of consumed energy. If the balance is violated there should be available ballast devices provided that wind energy intake exceeds consumption or automatic means that limit the power of the consumer. The scheme, which is a combination of the previous two, enhances the efficiency of wind energy converting. The last two circuits have got several times more units than the first one thus reducing total value of wind energy conversion. Also these two circuits provide an option to increase the fill factor load demand of the consumer to almost 1.

If there is a need to provide 80% of the customers' needs the intensity of the load should not exceed 0.25, i.e. the intensity of service flow should be four times higher than intensity flow applications.

When developing autonomous wind power systems with an asynchronous generator there should be made a focus on schemes that have the ability to increase the ratio of filled-load demand of the consumer.

PERMINOV Yu., KOKHANEVYCH V., MARCHENKO N. **Comparing end non-grooving generators for wind turbines with traditional generators.**

When developing new designs for wind turbines with capacity reaching 10 kW the developers prefer to install synchronous generators with permanent magnet excitation. There exist a number of such generators. When selecting a particular synchronous generator with permanent magnet excitation there should be analyzed their production technology, electrical and electromagnetic parameters and characteristics, which ultimately influences the cost.

This article suggests a comparative analysis of two generator types in the above power range, namely in the form of end construction with non-grooving stator or a conventional type with a grooving stator. As a permanent magnet the developers suggest NdFeB magnets or barium or strontium anisotropic ferrites. The analysis included electrical and electromagnetic parameters and characteristics of the generators while manufacturing technology wasn't considered at all.

The comparative study resulted in findings that considering electric and electromagnetic parameters the generator with an end non-grooving stator doesn't seem to have apparent advantages over traditional generator design with a grooving stator. At the same time with almost same facilities manufacturing generators with end non-grooving stators demands more permanent magnets thus making it more economically feasible than manufacturing traditional generators with a grooving stator.

Hydroenergy

VASKO P., IBRAGIMOVA M. **Small hydropower as a part of electricity sector in Ukraine.**

Integrated Power System of Ukraine is the backbone of the country's Electric Power Industry. It is a complex of power stations, electric and thermal networks, which are combined by a common mode of electricity and thermal energy production, transmission and distribution according to its centralized control.

In 2014 the total installed capacity of power plants in Ukraine was 55.11 GW. Most of the installed capacity comes from thermal power plants (34.3 GW), one quarter – from nuclear power plants (13.83 GW). The rest comes from hydroelectric power stations and pumped-storage hydroelectric power plants with the capacity of 5.85 GW and renewable energies – 1.13 MW.

Total electricity production in 2014 was 182.4 billion kWh/year. The main producers are nuclear (48.5%) and thermal (45.7%) power stations. Hydropower industry and renewable energy produced only 5% and 0.8% of the electrical energy respectively.

The total hydropower potential of Ukraine is over 44 billion kWh (including 3.0 billion kWh of small hydropower). Today the cost-effective potential is about 17.5 billion kWh, and it is already used about 11 billion kWh (60%). Thus, the untapped potential is about 6.5 billion kWh.

Hydroelectric power plants cover peak loads; control frequency and power; provide mobile emergency reserve of power in Integrated Power System of Ukraine.

At the beginning of 2015 Ukraine has 105 small hydropower plants with total capacity of about 82 MW and average annual electricity production of 250 million kWh/year. Most stations were put into operation in Vinnitsa region, where the total capacity is 22.45 MW. Kirovograd, Ternopil and Transcarpathian are the regions with the highest level of installed capacity.

According to "Energy Strategy of Ukraine for the Period until 2030" the potential of small hydropower is estimated at 1140 MW with annual electricity production of 3,34 billion kWh/year.

In Ukraine, the valid State Incentives for small hydroelectric power generation are: – privatization of small hydro power plants; – "green" tariff; – tax benefits; – preferential access to the electric network.

According to existing legislation small hydropower plant has to be privately owned or leased (large hydropower stations are not subject to privatization).

"Green" tariff is applied for almost all renewable energy sources (except for electricity produced by large hydroelectric plants). It is set for each entity by the National Commission for State Energy and Public Utilities Regulation. The tariff takes into account construction costs, maintenance of power plants and rate of return for electricity producer.

The scheme of stimulating the production of electricity through "green" tariff is set until January 1, 2030. The size of "green" tariff coefficient for electricity generated by power plants, which will be commissioned or significantly upgraded after 2014, 2020 and 2024, is reduced by 10%, 20% and 30% respectively. The state guarantees the purchase of electricity and its full payment.

In Ukraine, there are a lot of national laws and programs for protection, conservation and wise use of natural resources, as well as international treaties, conventions and protocols.

The current regulatory framework of the country provides good opportunities for the development of small hydropower.

Geothermal Energy

DUBOVSKYY S., TVERDOKHLIB O., KUDELYA P. **State, prospects and problems of district heating & cooling (DHC).**

In recent years, in the leading countries of the world there is a clear trend for the accelerated implementation of polygeneration caused by many factors, one of which is a factor of global warming.

Meeting the growing demand for air conditioning of residential and office premises distract themselves increasingly significant resources and energy consumption. To reduce these costs allows district cooling systems based on combined cold & heat and power generation (CCHP) involving secondary and renewable heat and cold. Along with fold reduction in primary energy costs and greenhouse gases emission compared with individual air-conditioning, such systems greatly simplify anti-peak management of electric power and enhance the loading of power equipment.

This work gives classification and specific examples of implementation CCHP in the world.

By example of district heating (DH) in Kiev there was considered the possibility of using such systems in Ukraine. Noted fold has increased in cooling degree-hours in Kiev for last 10 years with the achievement of 8500 degree-hours on 20ºC base with a positive trend. The potential demand in cooling for summer air conditioning connected to city DH rated as comparable with the needs for hot water supply. This leads to possibility of establishing energy efficiency district heat and cooling of the city based on existing capacity and infrastructure of DH.

Conceptual variants of realization municipal of district heat – cooling are considered based on the possibility of reducing the consumption of fuel and power, emissions harmful and greenhouse gases, improving load power equipment, solve the problems of anti-peak management of city power supply compared to the use of individual air conditioners. Indicated that favourable basis for large-scale implementation CCHP option is a combined heat and cold production on existing CHP with independent transportation.

The main tasks of further feasibility studies of CCHP defined comprehensive analysis of detailed engineering solutions for all options of systems based on an objective calculation of power consumption and cost supply of heat, cold and power in terms of their combined production.

KRAVCHENKO I. **Prospects for developing hybrid geothermal heat technologies in Ukraine at elaborated oil and gas fields.**

The article deals with the prospects to re-use deep mining oil and gas wells at elaborated hydrocarbon fields. The main task is to create geothermal energy mining and

accumulating units without drilling special wells. This will also provide financial savings for these works as they are quite costly.

This method uses hybrid implementation of individual wells, namely during heating seasons: from October till April as a geothermal heat source; and, from April till October as an underground heat accumulation battery that compensates winter consumption and accumulates additional thermal heat. Various power-consuming devices or technological equipment could serve as the heat source. These could be gas turbines plants at gas compressor plants, diesel engines, boosting compressors etc. And for sure renewable energy sources, namely solar collectors, could also be used.

The effect is achieved by creating double-piped U-type space by the so-called "pipe in pipe" scheme. The liquid heat carrier is flowing over in this space with the help of low-capacity reverse circulating pump. Water could serve as a heat carrier.

During the heating season the coolant is heated up by natural geothermal heat source. Using circulating pump it is lifted upwards over central coaxial pipe and then, when transferring the heat to consumers and being partially chilled out is goes downwards over inter-pipe space. When reaching the bottom of the well, the heat carrier again gets heated at the highest temperature level of the environment that surrounds the well.

When the heating season is over the pump switches to reverse rotation in the opposite direction and the coolant begins to move down the central pipe and upward through hole annulus. The coolant gets heated from outside heating source (i.e. exhaust gases from turbines or solar collectors) before getting pumped into the central tube. During this process it goes up the hole annulus and simultaneously transfers the heat to drive pipe covers of the space in the well where heat accumulation is done.

Accumulation process is in progress for 185 days, while accumulated heat consumption in combination with natural heat of the well – 180 days.

The depicted method has got a peculiarity. The external heat source can get higher temperature than the temperature of the natural source. In this case the accumulation battery will be much more efficient.

SHVETS M. **Experimental research of waste heat amount for a generator cooling system TVV-320, building No.1 at Kyiv HPP-6, which can be used for heat pumps.**

There has been experimentally determined the amount of waste heat for a generator cooling system TVV–320, building No.1 at Kyiv HPP-6. This heat can be used in heat pumps for heat supply.

To test this option there has been conducted a pilot study for a generator cooling system at building No.1 with different loads. The testing methodology has been developed. Methods to reduce measurements errors have been analyzed and suggested. The data building №1, Kyiv HPP, were gathered in the period 01.08.15 till 01.04.15 with various values of active and reactive power. The experimental data have been processed.

According to calculations the transformation ratio for the heat pump ranges 5 to 6 depending on the temperature of return water and temperature of the water that passed through the gas coolers. The thermal capacity of a heat pump ranges 1.8 to 3.6 MW depending on various loads.

Bioenergy

ZHOVMIR M. **Duration of volatile release at burning of straw particles and straw pellets.**

In Ukraine at current rates of economic activity economically expedient recourses of biomass for energy usage make 14.95 million t o. e. annually, of which resources of solid agricultural biomass reach 11.3 million. t o. e. (up to 76%). A small number of boilers with whole straw bales burning are operated in the country, and the expansion of their use is hindered by a number of technical, organizational and economic reasons. There are operated and under construction factories for straw pellets production with total output up to 325 thousand tons per year with the focus on export. Given the significant predominance of agricultural biomass usage of straw pellets is promising for small heating plants.

It is of practical interest development of burners for solid biofuels combustion with intensity of burning comparable with that for coal or natural gas, thus allowing the upgrading of existing boilers for more affordable solid biofuels without reducing their heat output.

Combustion of fuel particles begins with heating, drying, and thermolysis with emitting gas and vapour volatile substances. In this paper results of an experimental study in thermolysis duration of straw particles and a single straw pellets in air oxidizing environment at their rapid heating up in a muffle furnace, i.e. under conditions approximate to their burning in the furnace with the stationary layer, are presented.

For experimentation samples of wheat straw with particle length of 20 mm were prepared. From straw pellets the particles in the form of a right cylinder having mass 0.50 ± 0.02 g in dry state were cut. Apparent duration of volatile release τ_p was counted in seconds from the moment of particle placing into preheated furnace till end of volatile combustion. At temperatures of furnace 400 ... 500°C ignition of volatile is not happening, and the duration of their release counted till the end of visible smoke emission.

With increasing furnace temperature from 400 to 860°C values τ_p for dry straw particles decreases from 43 to 8 s, and at moisture content W = 30% – from 57 to 13 s.

In the same conditions values τ_p, for dry straw pellets with 6 mm in diameter decreases from 140 to 40 s, and in the case of pellets with moisture content W = 15% – from 200 to 52 s. Values τ_p for pellets with W = 10% are intermediate, at that the influence of moisture is more significant at low temperatures.

At the same condition for dry 8 mm pellets values τ_p decreases from 140 to 45 s, and in the case of pellets with W = 10% - from 195 ... 205 to 53...57 s. Further moistening of 8 mm pellets from W = 10% to W = 15% has diverse effect on the τ_p value for the pellets of different manufacturers.

As for straw particles and particles of straw pellets at

furnace temperature increase from 400 to 700ºC a drastic reduction of the volatile release duration is observed, and with further temperature increasing the volatile release accelerates slightly. Dependence of volatile release duration from temperature is exponential in nature.

At equal weight of straw particles and particles of straw pellets volatile release from straw particles occurs 3...5 times faster in comparison to that for straw pellets.

GOLUB N., DRAPOY D. **Hydrogen production from corn and sunflower wastes while enriching natural microorganisms association by *Bacillus* and *Clostridium* families.**

This research studied the ability of natural associations of microorganisms, isolated from soil and lake, to produce hydrogen from cellulosic materials in mesophilic anaerobic enzymatic process. It was proved that yield of hydrogen depends on the species composition of microbial associations. Clostridiит species dominate in associations isolated from soil, Bacillus species – in associations isolated from lake. Usage of the microbial association from soil gives 2.5 times more hydrogen than the association from lake. Enriching natural association from soil by microorganisms from Bacillus or Clostridium genus during the fermentation of corn and sunflower waste leads to a reduction of the lag phase and the yield of hydrogen compared to the natural association by 1.4 times in case of enriching by Clostridium species and by 3.5 times in case of enriching by Bacillus species. Enriching of natural association simultaneously by Clostridium and Bacillus genus leads to a significant reduction of the lag phase and to an increase of the hydrogen yield by 4 times compared to the natural association. Such conditions increase the hydrogen content in biogas to 85 ± 5%.

To inhibit methanogens, consuments of hydrogen, the fermentation was started with some air in the reactor. The dominance of both Clostridium and Bacillus genus of microorganisms increases the yield of hydrogen thanks to creation of anaerobic conditions by Bacillus genus which gives Clostridium genus a possibility to produce hydrogen.

ZUBCHENKO L., KUZMINSKYI Ye. **Light-dependent hydrogen production in fuel and biofuel cells.**

The article examines ways of hydrogen production by using solar energy. Brief review describes existing photoelectrochemical systems, which perform the electrolysis of water to obtain hydrogen. Using of different types of solar sells make hydrogen production possible without any external biases except solar energy.

The simplest way to get hydrogen by harvesting sun energy is usual electrolyses of water with sun battery as energy source. Photocatalytically hydrogen production is also possible in photoelectrochemical systems, where reduction of hydrogen takes place on the surface of semiconductor electrode.

It is examined the last researches on combining bioelectrochemical and photoelectrochemical systems. In photobioelectrochemical systems energy produced during metabolism of organic matter of nutrient medium by microorganisms-exoelecrtogenes, combined with solar energy assimilated by photoelectrochemical cell to form hydrogen molecules, making the system almost autonomous and depended only on the availability of nutrients for microbial biofilm and lighting.

Electrochemical potential required to hydrogen generation is – 0.42 V v.s. Ag/AgCl electrode. Bioelectrochemical systems, like microbial fuel cells, can theoretically generate electrochemical potential difference about 0.2 – 0.3 V. So, additional energy should be added to the system to produce hydrogen. Using of solar cells allows the system to be autonomous and independent of external energy sources. In our research we use silicon or other type of solar cells as additional energy source.

Photoelectrochemical cells may be used as additional source of energy, in this case, all system represents hybrid four-electrode construction. Another way is connection bioanode and photocathode.

It is possible to use wastewater, rich with organic components, as nutrient substrate (source of carbon compounds and energy). As a result we have system for simultaneous wastewater treatment and hydrogen or/and energy production.