# ABSTRACTS

**Y. O. Biletskyi**

## ENERGY-SHAPING CONTROL SYSTEMS FOR PERMANENT MAGNET SYNCHRONOUS MOTOR AS PORT-CONTROL HAMILTONIAN SYSTEM

One of the most common electromechanical systems is a system based on permanent magnet synchronous machines (PMSM). More and more complications of such systems and growth of control requirements leads to search for new control systems, which would enable to operate with complex objects, implement new control methods and were simple to set up. The latter include control systems based on energy approaches. Universal apparatus of control systems synthesis based energy approaches gave impetus to the rapid development of such systems. Great number of proposed synthesis methods and received with them control systems raises the problem of finding the optimal method of synthesis of control systems based on energy approaches.

The most promising methods of synthesis of such control systems consider control object as port-controlled Hamiltonian system. They include passivity-based control, energy-balance approach, interconnection and damping assignment and their combination with elements from linear and nonlinear control system theory. Regulator of PMSM electric drive obtained with passivity-based control is devoid of possibility to take into account losses in the windings and nonlinearity in the object during the formation of the desired equilibrium point, and any additional adjustment possibilities for speeding up / slowing down the processes. Energy-balance approach allows creating multi-parameter regulators that are very complicate in setting up and have bad static characteristics. Proposed in literature regulators synthesized with combination of energy-based approaches and elements from classic control system theory are complicate in setting up and can't guaranty system stability.

Based on conducted studies it was shown that the best static and dynamic characteristics are provided by regulator based on interconnection and damping assignment method. Recently this method was developed with parametrical synthesis, based on forming the desired characteristic polynomial of the transfer function of the closed-loop system. Parametrical synthesis procedure is new for energy-based approaches and requires further research.

**B. H. Boychuk, B. S. Kaluzhny, V. B. Tsyapa**

## STRUCTURED POLYNOMIALS CHARACTERISTIC FOR SYNTHESIS OF AUTOMATIC CONTROL

In solving problems of synthesis of closed systems on standard electric transmission function always considered the problem of choosing the minimum number of independent variable parameters that would ensure the desired settings transfer function coefficients and the wording of action sequences in this setting. In actual practice widely used system of subordinate regulation, subsystems are configured in series one after another. This approach can be applied only to certain structures of electric power, for example, without internal feedback, and when these connections are, then they ignore. If this is not correct, it developed some partial solutions, without the possibility of broad generalizations. In addition, the consistent setting does not use the maximum possible system performance, but it agreed for ease of configuration. In the traditional system of relative units free member and the oldest coefficient of the characteristic polynomial converted into units. To assess the effects of other factors on the behavior of the system in the systems of third order used Vyshnegradsky chart. For higher order systems this approach there. To overcome these disadvantages proposed structuring of certain characteristic polynomials. The system of any structure is represented as a structure that is based on a number of nested contours. It enables assessment of system behavior conducted by ratios characteristic polynomial coefficients. This allowed themselves to spread rates on certain basic factors. Analysis of many variants of the standard characteristic polynomials showed that the importance of these factors are

within a narrow range (approximately from 1 to 6), which allowed to name their initial coefficients system. A National Vyshnegradsky Chart in the coordinates of these factors. It is shown that the behavior described numerical values lower range of initial ratios compared with coefficients Vyshnegradsky. Powered application of this approach to calculating variations of third order.

**Yuriy Varetsky, Vitalii Horban , Yaroslav Pazuna**

## CHANGES OF VOLTAGE IN ELECTRICAL MICRONETWORK WITH HYBRID POWER PLANT

Limited natural resources and problems of environment has become an impact for widespread use of renewable energy sources. However, the use of any of these sources of energy is related to the problem of stochastic changes of energy. If you use a combination of these energy sources and complement it by battery, which is able to store energy during periods of high solar and wind activity, power ability of such a system will become less dependent on random changes in climate conditions. This combination of electric devices called hybrid power plant.

If the wind turbine and photo panels works in the composition of the hybrid power plant, the voltage change will depend on the nature of changes in the total active and reactive power that transmitted to the network. In general, for a long time cuts, the changes of solar radiation are also random. However, in some days it has quite certain time dependence.

If the control of reactive power of wind power plant is determined exclusively by its mode of operation, it can not affect on voltage changes that are made by the work of photovoltaic generator. If independent regulation of reactive power can be organized in the structure of the hybrid plant, these voltage changes can be minimized.

In local electrical networks the change of active power of wind and solar power plants that are caused by climate changes of the weather, can cause significant changes in voltage of joining points of consumers , the level of which significantly depends on method of regulation of reactive power of plant. Therefore, the regulation of reactive power must be taken into consideration during designing and equipping renewable electricity to local power grids.

**V. G. Gapanovych, Z. M. Bakhor**

## DESIGN OF A REGULATOR OF A STATIC THYRISTOR COMPENSATION UNIT FOR POWER SUPPLY SYSTEM OF MINING LOAD

General measures of quality of electrical energy in mining networks, which have significant influence on work of power consumption units, are deviation and fluctuation of mains voltage.

Compensation of voltage fluctuations on busbars of a mine power feeding substation, is possible using static thyristor compensators (STCs), implemented on a basis of existing batteries of static condensators (BSCs).

If the substation has BSC and its transformers are equipped with on-load voltage regulation (OLVR) device, it is reasonable to create STC on a base of BSC as follows: with installation of additional thyristor-reactor group (TRG), implementation of particular STC and integration of it with OLVR devices on substation's transformers into complex control system of power supply of mining load. In such case of complex control system integration, decreasing of rated power of TRG (by the side of autonomous running of the STC) is accomplished by restriction of regulation (stabilization) range of the STC by itself.

There are series-produced thyristor compensators of reactive power type TKPM in Ukraine. Factory default regulation system of TKPM units ensures full compensation of reactive power in phases of consumption point, but is inefficient when is used to stabilize voltage in point of STC connection due to lack of voltage regulation circuit. It causes that TKPM cannot take into account influence of changes of voltage mode in main electrical system on voltage on substation's busbars.

According to the matter described above, a structure diagram has been developed and STC operation state equations have been derived for the regional substation 330/220/110kV "Novovolyns'ka" of Western Energy System. STC considered here is implemented on a base of battery of static condensators with rated power 31 MV· A and thyristor compensator of reactive power TKPM-20/6 (20 MV· A, 6kV) as subsystem of complex control system of power supply of mining load. As a result, the system enables development of quality measures of electrical energy in mining electrical supply network.

**V. Hladkyj**

## MATHEMATICAL MODEL OF ASYNCHRONOUS MOTOR TAKING INTO ACCOUNT DEEP BAR EFFECT

Asynchronous motors are the basic consumers of electric energy in industry, agriculture and they are widely used to drive of most industrial mechanisms, that is why the research of processes in asynchronous motors by the mathematical modelling was always attentioned.

As known, in asynchronous motors the deep bar effect takes place, influencing on its static and dynamic characteristics.

The task of this research is development of mathematical model of asynchronous motor taking into account the deep bar effect, saturation of magnetic core and spatial harmonics of magnetomotive forces in their interconnection.

Asynchronous motor has an s windings on stator, distributed arbitrarily in slots along a period of the magnetic field and Z bars on rotor.

In a basis of mathematical model the following assumptions are fixed:

1. Hysteresis and eddy currents are neglected.
2. The magnetic field is divided on mutually independent the main magnetic field and leakage fields.
3. The toothed structures of stator and rotor are replaced by homogeneous in tangential direction layers, which magnetization curve in radial direction is equivalent to the magnetization curve of real slotted zones.
4. The magnetic field in active layer has only radial component, in the stator and rotor yokes – only tangential one.
5. The electric field in the deep bar has only component directed along the rotor bar.

With such assumptions the computation of magnetic field can be come to solving the one-dimensional two-point boundary problem. To solve this problem the method of trigonometric collocation has been used. To solve the equations describing deep bar effect the method of collocation has been used.

The system of algebraic-differential equations describing the electromechanical transients in the asynchronous motor contains the equations of magnetic state, the equations describing deep bar effect, the formulae of flux linkages and electromagnetic torque, the equations of electrical and mechanical states. The derivatives in this system of algebraic-differential equations are approximated according to the g-th order backward differentiation formula. The received linearized nonlinear system of algebraic equations is solved by the Newton method.

The worked out mathematical model of asynchronous motor with deep bar effect taking into account the magnetic core saturation and spatial harmonics of MMF allows to model behavior of motor in transients, steady-states, to carry out the estimation of influence of deep bar effect on static characteristics.

**I. R. Golovach, L. F. Karpluk, B. Y. Panchenko, V. B. Tsyapa**

## THE CONTROL SYSTEM OF THE DRIVE CRANK MECHANISM WITH NONLINEAR FEEDBACKS

For electric drives with speed control of now used thyristor converters with DC motors or frequency converters with AC motors. The formation of static and dynamic characteristics of modern systems of electric drive, as a rule, is carried out using a system with a subordinate regulation with internal loop current or torque

and the outer loop speed with the setting regulators on the principle of “technical optimization”. In this case, the electric drive system provides the main quality parameters of processes of regulation coordinates: overshoot does not exceed the allowable values ensures the stabilization of the speed when the load changes. But in process braking of the slider-crank mechanism with flywheels torque reaches negative values and slows down the speed of the rotating masses instead of taking the kinetic energy by increasing speed, which leads to deterioration of energy performance of the electric drive system. There are following ways of influencing the actuator to ensure operation without the entry of a suppress mode of recovery: the formation of soft mechanical characteristic, the introduction of a cutoff for the mode of recovery, gain torque feedback modes change sign. The disadvantage of these systems is a significant overshoot of torque. For the formation of the mechanical characteristics system of this type is proposed to apply additional feedback at speed, which is introduced in the transition to the second quadrant of mechanical characteristics. To ensure stable operation of the system at the same time increasing feedback gain will have to be signal by its derivative. The method of mathematical simulation to obtain graphs of transient processes in the electric drive with the proposed structures. The analysis shows that here the average value of the engine torque does not reach negative values, which corresponds to no regenerative modes of the drive. The speed of the engine with load, which corresponds to the second quadrant of the mechanical characteristic increases, which allows a rotating mass to store energy without the flow it through the engine. Overshoot only missing in the system and with the introduction of additional velocity feedback.

**Natalia Diachenko, Petro Baran, Victor Kidyba, Yaroslava Pryshlyak**

## SYSTEM SELF-TRAINING COMPUTER SIMULATOR FROM MANAGEMENT OF ELECTRIC PART OF POWER UNIT TPS

On statistics the far of accidents on thermal (TPS) and atomic power-stations (APS) arises up through fault of operative personnel. Therefore on the electric stations spare the special attention the question of preparation and retraining of operative personnel. For this purpose create the various systems of studies, which provide high quality of preparation of specialists from the operative management of power-stations power units.

One of methods of decision of this problem there is creation of the dedicaded systems of studies of operative personnel of the electric stations. The optimum educational system is the so-called trainer. Trainers are mainly developed from the operative switching, trainers from a management a caldron, a turbine. Educational systems from the management of power unit electric part very not enough.

The system of self-training developed as a separate module of computer simulator from the management of electric part of power unit TPS. For organization of process of studies of operative personnel the formed scenarios which are preliminary formed on the basis of the leading pointing from a management and instructions the modes on exploitation of technological equipment of power unit. A scenario is a successive list of actions of operator during realization of the mode of operations of electric part of power unit. On the basis of scenario exercises are formed, for example, synchronization of block for works with a tiristornim exciter, planned shutdown of generator from a network and others like that. Every exercise foresees possibility of input of various burdens during its implementation.

The self-training mode is foreseen by possibility of work of operator without limitations in time after the chosen scenario with the set disrepairs in a technological equipment or possible emergency situations. During implementation of the chosen exercise the foreseen possibility of appeal is for help to the educational system, sufferet errors are fixed, but actions of operator, which resulted in errors ignored, – correct actions are executed only.

The developed algorithm of the self-training mode allows an operator independently to realize the chosen mode of management power unit with automatic control of his actions the system of studies.

A computer simulator together with the module of self-training can be used both for preparation of operative personnel on the electric stations and for the students of electrical engineering specialities.

**N. B. D`iachenko, B. I. Durniak**

## RESEARCH OF INFLUENCE OF ERRORS OF QUANTIZATION OF TELEINFORMATION ON RESULTS OF NEUROMATHEMATICAL MODELLING

A certain percent of electric networks is partially telemechanized for this reason providing with entrance operational information for implementation of the full-scale operational analysis of their modes is the main problem as mathematical models are applied in the presence of the full determined entrance information. Besides efficiency of decision-making in the course of operational dispatching management of the modes of electric networks significantly depends on quality of teleinformation and in particular errors of quantization which comes to the quick and information complex (QIC).

One of ways of overcoming is higher than the mentioned problems there is an application of technologies of the artificial neural networks (ANN) for formation of models in case of partial information support where application of mathematical models is impossible.

These researches were conducted for an electric network of 110 kV. Studies of ANN it was carried out by results of mathematical modeling in technologically admissible range of change of the modes of loadings. The technique of study of ANN which is based on the principles of neuromathematical modeling can be described the following stages: the settlement scheme of an electric network is formed; a series of calculations of the settled modes in the functional and actual range of the modes of loading is performed; selection for study of ANN is formed; study of ANN is carried out; testing for the modes is held.

With a research objective of influence of errors of quantization of teleinformation which takes place in real operating modes of electric networks, the brought errors on tension in randomly the chosen set of the modes of test selection in test selection of entrances which was formed for carrying out a number of experiments of neuromathematical modeling.

Results of research of influence of errors of quantization of teleinformation (tension) on results of neuromathematical modeling lead up efficiency of application of synthesis of additional entrances and allow to claim that additional increase in quantity of entrances (method of synthesis of additional entrances or at increase in informational content) will allow to reduce an error. Recommendations concerning the choice of optimum architecture of ANN are developed.

**V. Konoval, A. Kozovyi**

## MODELING SYNCHRONOUS MACHINES OVEREXITATION LIMITERS TO ANALYZE POWER SYSTEM STABILITY

In Ukraine, during recent years active modernization of power station blocks is being carried out and this causes replacement of old excitation systems for new modern excitation systems of leading foreign companies/producers. This trend requires Ukrainian software complexes to more precisely perform modeling of synchronous machines excitation systems, including operation of excitation current limiters (overexcitation limiter, OEL, and underexcitation limiters, UEL). International standard IEEE Std 421.5™-2005 proves importance of such changes.

The limiting action provided by OELs must offer proper protection from overheating due to high field current levels while simultaneously allowing maximum field forcing for power system stability purposes. Limiting is typically delayed for some period to allow fault clearing.

The model described herein is intended to represent the significant features of OELs necessary for some large-data from generator owners. An attempt to include all variations in the functionality of OELs and duplicate how they interact with scale system studies. It is the result of a pragmatic approach to obtain a model that can be widely applied with attainable the rest of the excitation systems would likely result in a level of application insufficient for the studies for which they are intended.

Digital systems define the inverse-time limiter characteristic using an equation with variable parameters, and may adhere to standard curve definitions, such as in Equation (1) or those found in IEEE Std C37.112™-1996. However, the inverse-time characteristics of older systems are dependent on the designs and may vary in

shape. Most types of systems can be adequately modeled by a curve fit using the characteristic Equation (1) where *A*, *B*, and *C* are constants (see IEEE Std C37.112-1996).

For example, we used operation conditions of overexcitation limiting blocks installed at Rivne NPP power blocks with new exciter SEMI Exciter (AEG). To test performance of overexcitation limiting block we simulated emergency condition with voltage collapse in stressed power systems. The experiment confirmed the correctness of overexcitation limiting block mathematical model.

**A. S. Kutsyk, M. B. Semeniuk, V. O. Misiurenko**

## MATHEMATICAL MODELING OF A SYNCHRONOUS GENERATOR MODES WITH PULSE WIDTH REGULATION OF AN EXCITATION

The paper presents an analysis of synchronous generator modes in the electrotechnical system (capacity of 3,5 MW) with pulse-width control excitation current, including the initial excitation mode, generator switching-on to the power load with active and reactive power load.

In the electrotechnical system with synchronous generator it uses static self-excitation system. Formation synchronous generator excitation current is provided full bridge DC/DC converter with symmetric control, based on four insulated gate bipolar transistors. IGBT switching frequency is 1 kHz.

To ensure the necessary regulation quality of the output voltage of the synchronous generator in the electrotechnical system is proposed to use automatic excitation regulator that implements a proportional-integral or proportional integral differential voltage generator regulating with an external loop of stator voltage regulation and inner loop of excitation current regulation.

The research results of electrotechnical system with pulse-width adjustment of synchronous generator excitation current and PI voltage regulator show that the research system provides high quality of generator voltage control, including the no voltage overshoot in initial excitation mode of generator, no voltage regulation static error and a slight (1.5%) dynamic error in generator load modes. In addition, full bridge DC/DC convertor with high frequency modulation (up to 10 kHz) provides minimum pulsation of excitation current (up 0.08%). Such excitation current ripple is less than in the case of using semiconductor controlled rectifier for excitation current regulation, which works with large thyristor opening angle in nominal mode. In this regard, such excitation control system is perspective for use in power plant with synchronous generators of relatively small capacity (10 MW).

**V. V. Kuchansky**

## EXPRESS-ASSESSMENT OF RESONANCE OVERVOLTAGE ON ABNORMAL MODES IN MAIN ELECTRICAL POWER GRIDS

The study of the origin conditions and possible consequences of abnormal modes power electrical networks with extreme values parameters, such as overvoltage traditionally performed using mathematical models with linear and symmetrical elements. This is due to great experience in the development and use of this class of models in practice, since the basis for decision-making in the design and operation electrical networks is simulation results primarily normal modes. At the same time, a more detailed analysis shows that the presence in modern electrical networks sources of distortion, mainly unbalance, influences the current values of the parameters modes, including the probability of transition these values through thresholds.

Trends of modern electricity power grid point to the growing role of extra high voltage (EHV) transmission lines as those that constitute the system and interconnect systems. It should be noted that the study of overvoltage for this class lines must be done very carefully, particularly with regard to the impact of sources of distortion. This is due to the lack of practical operational reserve insulation, designed for extreme values, as a such reserve for EHV is expensive. Thus, analysis of the possibility of overvoltage in EHV lines should be done

not only in normal, but also for abnormal asymmetrical modes. Operating experience shows that such analysis can be performed using: experiments on operating equipment use of analytical methods, mathematical and simulation on computers. Because of the danger of unexpected transition from abnormal network modes in emergency mode, experimental studies are of limited use, and therefore to study the abnormal overvoltage typically analytical methods are used. However, as shown, simulations require skills and experience in special simulation programs, which complicates assessment of appearance over during operation or design.

Thus, the improvement of analytical methods and the development of appropriate rapid assessments to study the abnormal surge in their occurrence, development and existence, the solution of which is devoted to this work, there is an actual scientific and practical problems. In the paper, the application of the developed express-assessment is considered, which can determine the entering into the range in voltage range resonant increase.

**G. M. Lysiak, I. I. Ostrovka, I. O. Sabadash**

## SQUARE-INTEGRATED METHOD OF IDENTIFICATION OF EMERGENCY SITUATION OF LINE TRANSMISSION

In practice of exploitation of electric networks known complex of organization of work relay protection in the case of lines of considerable length when it is difficult to distinguish regime three-phase short circuit from normal exploitation regime, because values of the coordinates are proportionate. The coordinates of the three-phase short circuit are similar to the load surge and much in common they have in the case of start (self) powerful engines.

The traditional way of protecting the transmission line of networks of 6 – 35 kV is the current cutoff with dependent or independent time delay and instantaneous overcurrent. Operation times of current cutoff without time lag amounts to 0.06 – 0.1 s, it is necessary for coordination of work of protection with the action dischargers which triggered during atmospheric discharges. For the protection from slightly different approach for determining emergency situations high-speed mode current protection can be included.

It is proposed a square-integral method of recognition of regime of three-phase short circuit and starter motors. This method is determined in the difference square integral instantaneous values of current travelling period and square instantaneous values of current prior period and comparison of the square-integrated features (SIF) anomalous situation with the standard transition SIF respective situation. The criterion for recognition regime three phase short circuit and start the engine is the ratio of the transitional SIF phase. In the case of three phase short-circuit these relations are changing in the vicinity of 1 relative units (r.u.) and the amount of phase relations change, respectively, in the vicinity of 3 r.u.

The use of a square-integral method allows to identify high-speed emergency lines of considerable length – three-phase short circuit.

Parameters of a square-integrated engine start characteristics depend on the distance from the source to the site of the engines. Since this distance it is always known, the correction of the latter is not difficult.

**article O. Yu. Lozynskyy, Ya. S. Paranchuk**

## STRUCTURE OF MULTICONNECTED CONTROL SYSTEM FOR ELECTROTECHNOLOGICAL COMPLEX “ARC STEELMAKING FURNACE – SUPPLY NETWORK” MODES CONTROL

The structure of multicircuit multifunctional coordinate-parametric system for control of electro-technological complex “arc steelmaking furnace – supply network” modes was developed. This system features extensive opportunities to implement multi-criterion optimization of steel melting process. This is achieved by including into the system structure additional purely electrical high-speed circuit of specific mode coordinate

(current, arc power, furnace reactive power, etc.) control. Such solution makes it possible to get much higher dynamic accuracy of electric mode coordinates control and using complex system approach increase integral electrotechnological efficiency indices and electromagnetic compatibility of electric arc furnace and supply network. This is achieved by combining advantages of electromechanical and electronic contours of electric mode coordinates control: electromechanical contour assures the reliable arc ignition and arc length control under the influence of dynamic random perturbations of arc length in low frequency range (0-6 Hz), and 30-100 times more fast-acting electrical contour provides the system with astatic properties of electrical coordinates control. Utilizing such a system solution one obtains functional ability of real-time implementation of required electric arc furnace artificial external characteristics: the desired arc current vs. arc voltage dependency that meet put quality criteria of electric modes control. The last fact greatly expands the functional abilities for the implementation strategies of multicriterion optimal control of steel melting in arc furnaces, and significantly improves the autonomy of phase channels of electric mode coordinates control.

**V. Malyar, O. Hamola, V. Maday, I.Havdo**

## THE STUDY OF SINGLE PHASING MODE OF THREE-PHASE ASYNCHRONOUS MOTOR

The problem of calculation of transients in asynchronous motors which works from single-phase network with capacitors in a single phase is examined in the paper. The basis of the algorithm is a mathematical model of asynchronous motors. This model takes into account magnetic core saturation by main magnetic flux and leakage flux and also phenomena of skin effect in the bars of the rotor. The three-phase system of co-ordinates is used for research of dynamics. In this system of co-ordinates the stator winding does not transforms, and the rotor winding reduced to the three-phase immobile winding. The phenomena of skin effect in the bars of the rotor is taken into account by the division of bars of rotor on a height on ***n*** areas. Thus, such mutually immobile windings is examined in the mathematical model of motor: the three-phase stator winding and ***n*** of three-phase rotor winding. The transient phenomena compute by numeral integration of the system of differential equations. This system consists of equations inductive coupling circuits of stator and rotor and equation of dynamics of rotor. The elements of matrix of Jacobi of this system of equations are own and mutual differential inductances of motors circuits. These elements settle accounts on the basis of magnetization curve of main magnetic flux and leakage flux of stator and rotor windings. On the basis of the worked out algorithm the made program of calculation is for research of dynamics of processes with the different value of capacity of capacitors. The capacitors capacitance gets out from the condition of providing of starting electromagnetic torque and it must be checked in the dynamic modes in that there can be overvoltage as a result of the resonance phenomena and self-excitation. The results of mathematical design are illustrated by examples.

**Volodymyr Moroz, Vira Oksentyuk, Petro Bolkot, Kostyantyn Snitkov**

## EFFECT OF THE DATA BIT WIDTH ON THE ANGLE ACCURACY OF THE INDUCTION SENSORS

The accuracy analysis method for determining the signal phase of the induction encoder de-pending on the digit capacity of the input data obtained from the sensor via analog-to-digital converter was presented in this article. It is shown that only digital signal processing along with electronic circuit is possible to implementing a high accuracy angle using inductive sensors.

The phase determining method based on a known method using the invers tangent and invers cotangent functions, which found the maximum and RMS errors de-pending on the digit capacity of the input data. The analysis was performed for both low-cost 10- and 12-bit ADC, and for precision 16-bit ADC. The known relationship that defines the invers tangent function by the definite integral was used to realize the invers tangent function in digital data processing system with induction sensor.

The impact of input data's digit capacity and the number of intervals on the interval 0-45 degrees on the accuracy of the invers tangent function integrated implementations was investigate for numerical definite integral formulas of different orders. Analysis performed for the implicit and explicit integration formulas from 2nd to 5th order. Studies have shown that the use of mathematical methods of information processing makes it possible to obtain results with higher accuracy than the accuracy of the source data.

To confirm the effectiveness of the implemented mathematical tools of digital measuring system experimental research was con-ducted in the laboratory NDL-68 of Special Design Bureau of electromechanical systems of National University "L'vivska politehnika". Experiments were conducted with an experimental model of high-accuracy angle induction sensor with 16-bit digital signal processing from the sensor windings and provide angular resolution not worse than 2". The results were briefed in the table and graphs.

It was shown that the use of mathematical methods of information processing enables you to get results with higher accuracy than the source data accuracy, the following conditions:

- use the arctangent (arc cotangent) function to determine the phase windings of the induction signals from the sensor;
- use third and higher orders numeric integrators for the arctangent function.

**K. Pokrovsky, M. Kuzhelev**

## ASSESSMENT OF EFFICIENCY OF WIND FARMS BASED ON DATA FROM PUBLIC SOURCES

There are represented assessment of efficiency of wind farms in the Carpathian region based on data from public sources and showing technic and economic indicators of power station.

One of the problems of wind energy is determined insufficient information available about the effectiveness of wind farms in the wild, due in particular to commercial issues of use.

This applies to the performance of wind loads in mountainous regions. Lasting licensed wind measurement parameters for access in difficult conditions is also associated with a high cost of equipment and operations.

To increase the growth rate of wind power should provide a broad introduction of simplified and low-cost methods for assessing the economic efficiency of wind turbines and wind farms.

This applies particularly to the impact of state regulation of "green" electricity tariffs, free access to the results of measuring the wind potential in different regions.

These methods are based on sources with free access and verified information.

For example, in the work of the results of evaluating the economic efficiency of 10 wind power generators power station with a capacity of 3.3 MW per unit based on sources with free access to the Internet.

It is shown that in this way you can get Veybul's analytical division of wind loads for the selected area.

Using the wind turbines options can calculate the necessary preliminary analysis of the economic efficiency of wind power options – the use of installed capacity, efficiency, annual production of electricity, the average wind speed during the year.

The obtained characteristics allow approximately estimate the investment, expenditure and profitable components of the project at the stage of pre-project work.

These parameters take into account the current state of regulatory and legal documentation.

As a result of the estimation of costs for wind turbines and their installation and operation, profit margins and estimated payback period.

It is shown here the high efficiency of the implementation of wind power in terms of the Carpathian region.

**O. M. Ravlyk, V. J. Stecyk**

## SIMULATION OF SWITCHING PROCESSES IN LINES EXTRA-HIGH VOLTAGE 750 KV

On EHV lines during switching may occur dangerous levels of switching overvoltage, which can cause to failure of linear or substation equipment as a result of damage its isolation. So switching processes and overvoltage what accompanying them, put forward number of specific requirements for equipment and its isolation, and safe indicators of work can be achieved only on the bases of more accurate calculation mathematical models.

In the submitted article describes a method that makes it possible to assess the accuracy of the mathematical model EHV lines depending on the concentration of her parameters. In the program complex "RE" for 750 kV lines "Vinnytsia – Zahidnoukrainska" calculated linear parameters and developed three models which consisted of 12.24 and 48 cells respectively, and calculated time delay of voltage at the end of the line. Based on analytical calculations was received the phase velocity in line and calculated the time necessary voltage to achieve its opposite end. Comparing analytical and calculated results of delay time of voltage in the line can be said about increase the accuracy of the mathematical model EHV line with the increasing number of cells.

To test the method in the software complex "RE" for the line 750 kV "Vinnitsa – Zahidnoukrainska" was investigated typical plan and emergency switching process what taking place in operation of line. As a result of the simulation was received multiplicity overvoltage, which confirmed the high accuracy of the developed mathematical model and its effectiveness. Also was calculated the maximum value overvoltage at process of elimination of single-phase short circuit in the cycle of Single-Phase Auto-Reclosing.

**Y. I. Fediv, O. M. Sivakova**

## REACTIVE POWER COMPENSATION IN POWER SUPPLY SYSTEMS WITH POWER RECTIFIERS

For the efficient and reliable power supply of load centers, it is important to maintain constant reactive power balance both in steady and transient modes of distribution mains. For the provision of reactive power balance, it is necessary to have controlled high-speed sources of reactive power with the possibility to overload them during transition processes. Traditionally controlled power rectifiers consume reactive power due to artificial shift of the main current harmonic in relation to voltage supply during their control of the change in the entry points of semiconductor valves work.

For power supply systems with high-power controlled rectifiers of processing systems, it is offered to solve the problem of providing reactive power balance by dividing them into two groups. The need for reactive power, consumed by the first group of rectifiers, performed on semicontrolled valves, must be provided by the group of rectifiers, performed on fully controlled semiconductor valves, in the mode of being ahead of the main electric current harmonic through coordinated control of the change in the moments of valves closing time , i.e. in the mode of generating reactive power into the power system.

We received analytical dependence for secondary and higher current harmonics of load unit with an arbitrary number of power rectifiers, controlled in the suggested manner. They allow calculating the amplitude and phase of each current harmonic in order to calculate the energy performance and evaluation of electromagnetic compatibility of rectifiers with supply network.

Examples of calculating the controlled characteristics of rectifiers are provided, as well as two indicators regulated by state standards as for the quality of electricity – THD and the ratios of the *n*-th harmonic component of current for three-phase bridge rectifiers.

The results allow justifying the choice of the control mode for rectifiers of processing systems and the choice of the type of semiconductor valves for their equipment. With their help one can solve problems of searching for the optimal control algorithms of concurrent rectifiers in the power supply system according to the given criteria.

**M. A. Jatsun**

## CORRELATION OF INDUCTANCES OF LEAKAGE SCREENED CYLINDRICAL ALIGN WINDINGS ON FERROMAGNETIC TO THE CORE.

At determination of parameters of equivalent circuits of transformers inductive supports of dispersion of windings of transformers determine as a half of inductive resistance of short circuit. Such estimation of resistances of dispersion is close. Therefore the question of determination of correlation of inductive resistances of dispersion of windings becomes actual after the known inductive resistance of short circuit of these windings at presence of ferromagnetic screens, that in the calculation models of inductances of cylindrical align windings on ferromagnetic to the core represent in power oily transformers and many reactors of wall, bottom and overlay of tank, and also yoke beams. Such calculation model is used by an author for a case ferromagnetic core without losses and reserved screens in form two cylinders and two identical pucks that is accepted with infinitely large magnetic permeability or superconductivity.

In the known literature inductive supports of dispersion of such windings are determined after close formulas (for plane-parallel magnetic-field) with the considerable warning (by suppositions), and by an author certain inductances of dispersion of cylindrical align windings on ferromagnetic to the core in case of plane-meridional magnetic field.

Investigational correlations of inductances of dispersion of cylindrical align windings are on ferromagnetic to the core depending on geometrical sizes and mutual placing of windings, sizes and properties of screens.

The got expressions give an opportunity to investigate influence of geometrical sizes and mutual placing of windings and also sizes and properties of screens on inductance (inductive supports) of dispersion (and short circuit) of cylindrical align windings on ferromagnetic to the core. If the height of windings is equal to the height screen, then harmonic constituents the absent and basic constituents of parameters for ferromagnetic screens become exact results.

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## LIMITATION OF MAGNETIZATION CURRENT INRUSHES IN ELECTRICAL POWER SUPPLY SYSTEM OF ELECTRIC ARC STEEL-SMELTING FURNACE WITH PRELIMINARY COMMUTATION OF THE FURNACE

The process of steel smelting in electric arc steel-smelting furnaces (ESSF) requires frequent switching of idle furnace units, accompanied by high-multiplicity magnetization currents inrushes (MCI). Electrodynamic rushes, caused by MCI, applied to windings of network transformers, affect loosenings with subsequent failures of transformer units.

Analysis of main factors that influence the value of MCI has offered the way to limit them using staged process of turn-on of furnace units.

One of the general influence factors, which cause value of MCI is amplitude of mains voltage: amplitude of magnetic flux in a magnetic core of a furnace unit is dependent on it through inrush current. The sense of the means of MCI limitation proposed is that turning on the furnace unit is carried out in two stages. On the first stage decreased voltage from an independent power supply is supplied to windings of the furnace unit. Voltage decrease is attained by including of a current-limitation reactor into the circuit of the independent power supply unit. In order to achieve goals needed, voltage value is to be adjusted due to required limit of MCI on the first stage. After some delay, caused by time, required to calm down transients of the first stage, the windings of the furnace units take nominal voltage from the mains supply. MCI appeared are dependent to voltage increase value (difference between nominal and decreased voltages of the power supplies). If the voltage of the first stage is adjusted right way, MCI is not supposed to overcome limits, acceptable by transformer vendor due to mechanical strength of windings.

The research hereinafter has been performed grounding on mathematical experiment. Results of the named experiment have shown that application of a current-limitating reactor with inductance of 0,4 Gn/phase allows to avoid unsafe values of MCI in the windings of the mains transformer while ensuring acceptable limits of overloading of an auxiliary transformer.

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## BASICAL ASPECTS OF INTEGRATION WIND PLANTS IN ELECTRIC SYSTEM

The integration of new capacities of Wind Power Plants (WPP) into Power Systems (PS) of different countries shows the expediency and high efficiency of wind power use for electricity production. Taking into account the continuously variable nature of wind power and increased share of WPP at PS more technical aspects their collaboration require detailed consideration. First and foremost these are the requirements of consumers to power quality, and system operators, and owners of WPP must be taken into account. A choice of WPP location requires detailed analysis not only on the available wind resources, but also at the choice of the point of common coupling (PCC) of WPP to Power Grid (PG), since this leads not only to a change in the infrastructure of PG, but will cause technical problems. Considering the international demands of the Technical Requirements, in particular to frequency control, WPP should be directed to better adaptation of the control and protection requirements. The conditions of the choice of the PCC of WPP to PS and conditions that must be met for their collaboration are shown schematically and are described. The effects of WPP integration into PS are analyzed on the local and general levels. The special attention is paid to frequency control of PS, in particular to analysis of international and Ukrainian requirements for the frequency range at which WPP must remain in operation. Regardless of the share of electricity production by WPP PS should continually provide customers with electricity and maintain the balance of power. In prospect effective integration of WPP into PS has the greatest potential for extensive use, particularly in Ukraine. The local WPP impact on PS mainly depends on the type of wind turbine generator, the general depends on the share of WPP as part of PS. The modern WPP should be directed to better adaptation to the PS requirements using extended and local control and protection. To maintain the "adequacy" of PS it is important to prevent the loss of a large number of the generation by WPP during faults in PS. Measures of the prevention short circuits, voltage control and additional automation, methods of the frequency control of WPP and PS should be improved.