ABSTRACTS

Peter Baran, Kidyba Victor, Yaroslava Pryshlyak, Marian Dembitskyy

COMPUTER SIMULATIONS MANAGEMENT ELECTRICAL PARTS OF TPP

High quality training, operating equipment of thermal and nuclear power plants, is one of the conditions secure, reliable and cost their work. In this connection, much attention is paid to creating effective systems of training and support for high-level training operating personnel TPP and NPP.

A number of scientific and engineering teams working on a study of operational staff TPP and NPP. The market is saturated with different systems of education, but education systems of boilers, turbines, generators and other sophisticated technological equipment is still small.

The mathematical model of the electric power station unit, which consists of separate models: from turbine rotation speed control; Admission electricity system; turbogenerator; excitation systems (primary and backup) with automatic adjustment of excitation current; the electrical power of their own needs; relaying; control and signaling.

Based on a mathematical model unit was formed digital model using object-oriented programming. Software implementation of digital model implemented in the programming environment Lazarus 1.2.2. To create graphics elements used management board 3d-environment Blender 2.69.

Computer training simulator for the operational management of electric power part was realized for the power capacity of 300 MW. This is due to the fact that Ukraine is the largest thermal power units of the same capacity of 300 MW (7 TPP).

In mathematical model which reflects processes in the electrical power of the developed subsystem of training operational management of the electrical part of the unit.

The computer simulator is a system of training of operating personnel management part of the electric power in stationary and especially in emergency situations and can increase the skill level of operational staff.

A computer simulation implemented in the educational process at the department of electrical systems and networks in the discipline "system of production and distribution."

L. J. Glukhivskyi

MODELLING OF PROCESSES IN ASYNCHRONOUS MOTOR WITH A PULSATION LOAD ON THE SHAFT USING THE DIFFERENTIAL HARMONIC METHOD

In paper is considering the method of application of differential harmonic method (DHM) for the numerical simulation of large transient oscillations (LTO) and large established oscillations (LEO) in asynchronous motor (AM) in the presence on its shaft periodic pulsating load.

It is proposed to doing analyze processes in AM in the system mutually perpendicular axes $x-y$, rotating synchronously with the rotating magnetic field. Currents of windings AM, converted to the axes $x-y$, in LTO except permanent components have established variable fluctuations with a frequency of moment of resistance on the shaft. The application of DHM makes it possible to determine the solutions of nonlinear differential equations in the axes $x-y$, describing large fluctuations in AM (nonlinearity is caused by the presence in system of equations of equation of mechanical equilibrium and taking into account the magnetic saturation of AM), in the form of truncated Fourier series. Their amplitudes of harmonics in the LEO are permanent and in LTO – variables over time.

There is expounded the transformation of differential equations of large fluctuations in AM in axes $x-y$ to another system of differential equations (in the case of analyzing of LTO) or to another finite equations (if the case of analyzing of LEO), variables of which are the amplitudes harmonics truncated Fourier series. The new system of equations called DHM-equations.

Iterative method of Newton is proposed for solution of the finite DHM-equations in the case of simulation of LEO and offered zero-approximation method of determining the values of the amplitudes of harmonics the use of which guaranteed fast convergence of the iterative process of solution. In the case of modeling of LTO the differential equations is proposed integrate by one of the numerical methods, in particular – Kutt-Merson method.

There are described the algorithms of solving finite and differential DHM-equations describing LTO and LEO. In paper are analyzed of results of simulation of LEO for AM capacity of 1000 kW.

B. V. Dmytryk, O. M. Ravlyk

THE DETECTION OF WINDING SHORT CIRCUITS IN SINGLE-PHASE DOUBLE-WINDING TRANSFOMERS

The experience of the power transformers' operation in power grids showed that winding short circuits (the flashover of winds' insulation in one winding) are the most dangerous breakdowns. It can cause the extensive fire of transfomer. While the injured winding of transfomer can be remote and fixed, the damaged core is beyond repair. In oil transformers there is a gas protection which detects the oil breakdown products in the tank during the winding short circuits. By the deficiencies of using oil transformers, there was created the analog with dry insulation and air cooling. However, existing relay defenses of both oil and dry transformers can't provide full protection.

In this article there is offered a new method to identify winding short circuits inside a power double-winding transfomer. It reliably reveals short circuits of a big quantity of winds as well as only few of them. To test this method there was used a simulation model of a single phase transformer with certain load connected to its secondary winding in software package «RE». The main idea is based on the phenomena of transformer's alteration of parameters during the emergencies. Since, the winding short circuit is an emergency mode, the options of the equations differ from the nominal values, especially the winding's resistance.

The method is based on the measurements and analysis of the instantaneous voltage and current of windings. During the emergency mode we analyze the equation of the unharmed winding, express the magnetizing current value and then substitute it into the equation of emergency winding. The determination is conducted during the each half of the period. If the resistance differs from the value calculated in the previous step the output signal will be "1". To prevent false triggering during the abnormal modes which, on the other hand, are suitable for transformer, there were investigated other processes: no-load mode, nominal load mode, and external short circuit mode. According to the result the method shows absolute selectivity.

Considering, that the identification method is based on the main physical laws of magnetic fields and Theoretical Foundations of Electrical Engineering, it is suitable for different types of transformers.

A.B. Zhurahivskyi, A.J. Jazeyko, R.J. Masliak

FERRORESONANCE PROCESSES ON ELECTRICAL NETWORK FREQUENCY AND SIZES OF PREVENTIVE RESISTORS FOR IT DISRUPTION

The networks with isolated neutral are considered in the article. Such networks have a number of well-known advantages and disadvantages. One of the main disadvantages of such networks is the possibility of appearance the ferroresonance processes in them. The models of different voltage transformers types and the models of network 6-35 kV were made up. As the study of the ferroresonance processes on the subharmonic frequency was researched many times, the main focus is given to the research of possibility the ferroresonance processes appearance on 50Hz frequency in n 6-35 kV networks for different types of voltage transformers. The ranges of capacitive ground fault currents that enable the emergence of such processes are established. Studies have shown that these processes can occur only at very small capacitive current earth fault, which corresponds to the operating mode without network load. By magnitude overvoltage such processes are commensurate with ferroresonance processes on other frequencies. The possibility of disruption the ferroresonance processes through extinguishing resistors, which momently turn on a winding voltage transformer is also investigated. There is also established that sizes of extinguishing resistors depend on the type of voltage transformer and the voltage network. For the most common types of voltage transformers, sizes of extinguishing resistors are established that assuredly extinguish the ferroresonance processes. It is proved that resistors with the value of 25 ohm, which are foreseen by regulatory documents, can prevent only the ferroresonance processes at a frequency network. For reliable protection of the voltage transformers from damages by ferroresonance processes, extinguishing resistors should be connected to each of the voltage transformers installed in the network. Conducted studies make it possible to conduct more accurate analysis of the electrical grid and determine the possibility of appearance the ferroresonance processes in it. And also they allow developing more reliable security devices which assuredly will provide the absence of ferroresonance processes in the network.

Yu. A. Kens, R. Ya. Ferensovych, N. B. Diachenko

SIMPLIFIED ANALYSIS OF STEADY-STATE OPERATING MODE OF A ONE-STAGE CURRENT TRANSFORMER AFTER THE OPENING ITS SECONDARY WINDING

Current transformers (CT's) operate in both steady-state and transient operating modes of electrical networks, in which they should provide corresponding characteristics and accuracy of primary current transformation.

The opening of CT secondary circuits is accompanied by the sharp increase of magnetic flux in the magnetic core as a result of disappearance of demagnetizing magnetomotive forse of the secondary winding that will cause an increase of active losses in the magnetic core, its overheating and, as a result, insulation damage of windings and in the end – a failure of the CT.

Besides, the magnetic flux induces in the secondary winding of CT high-voltage pulses with an amplitude which can achieve values of several kilovolts (in contrast to several tens of volts in the normal mode). Such overvoltages on CT secondary winding terminals cause, as a rule, insulation damage of secondary current circuits, relaying and automation systems, especially modern microprocessor devices, which are connected to this winding. Also they can cause an electrical injury of attending personnel. Therefore the questions of safety service of CT's and a designing of the reliable protection methods from overvoltages after the opening their secondary circuits are extremely topical.

The analysis of the steady-state operating modes of CT type TPSHL-10 with using its simplified calculation scheme and two part-linear weber-ampere characteristic of magnetic core is carried out by using computer simulation. It gives general characteristic of transient electromagnetic processes in the transformer after the opening its secondary circuit. The obtained waveforms and corresponding calculation results of CT operation mode graphically characterize specialities and a danger of its operating mode with open secondary circuit and can be used in the methods of analytical calculations of the voltage amplitude on the open secondary winding terminals of the one-stage CT.

V. Konoval, A. Kozovyi

MODELING SYNCHRONOUS MACHINES UNDEREXITATION 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.

UEL acts to boost excitation for one or more of the following purposes:

a) To prevent operation that jeopardizes stability of the synchronous machine or could lead to loss of synchronism due to insufficient excitation.

b) To prevent operation that would lead to overheating in the stator end region of the synchronous machine, typically defined by the extreme underexcited region of the machine capability curve.

c) To prevent loss-of-excitation relays from operating during underexcited operation.

We analyzed operational aspects of underexcitation limiters in depth; that allowed us to cover wide range of UEL usages and to narrow them to two types. Mathematical and digital models were developed for two types of underexcitation limiters:

- Circular characteristic (Type UEL1)
- Single- or multiple-segment straight-line characteristic (Type UEL2)

For example, we used operation conditions of underexcitation limiting blocks installed at Rivne NPP power blocks. To test performance of underexcitation limiting block we simulated emergency condition: switching off shunt reactors of 750 kV at Zakhidno-Ukraiinska substation and increasing voltage in the power network. The correctness of underexcitation limiter performance was analyzed in relation to power blocks active power.

We tested the coordinated work of existing characteristics of underexcitation limiting block with real characteristics of excitation loss protection. Protection of excitation losses works selectively after generator excitation loss appears and does not work when underexcitation limiting block runs, and this proves correctness of both existing characteristics and developed UEL mathematical and digital models.

B. L. Kopchak

SYNTHESIS OF FUZZY FRACTIONAL CONTROLLER AND STUDY OF ITS INFLUENCE ON ELECTROMECHANICAL SYSTEMS ROBUSTNESS

The development of modern electromechanical systems aims at the search of approaches to the implementation of robust control. The use of fuzzy controllers can solve a number of problems, such as optimization of nonlinear electromechanical systems, minimizing the influence of unsteady phenomena, etc. Given the fact that some of the phenomena in electromechanical systems are fractal in nature and the dynamic processes in the power circle are described by differential equations of fractional order, the use of a fuzzy controller fractional I and D components is quite feasible.

In the article the modification of the characteristic polynomial method for the synthesis of fractional PID controller for desired quality of the transition process has been offered, including its approbation as exemplified by the voltage control of self-excitation induction generator in view of its non-linearity characteristics. The impact of such controller on electromechanical system robustness has been examined. In particular, provided the results of transition function quality by changing certain parameters are not satisfactory, such as the degree of disagreement with the desired quality of the transition process, the paper proposes to make calculations of controller for different values of changeable control object parameters and implement the controller with the adaptation to some informative parameter (the original coordinates, etc.).

One approach to implement such control is the use of fuzzy logic. It has been shown through simulation in Matlab Simulink package that the use of fuzzy fractional unit allows to synthesize the controller that provides a high degree of robustness to nonlinear parameter changes of electromechanical system control object.

The suggested approach to building robust electromechanical systems is universal and does not depend on the number of parameters (n), which vary within certain limits, but their increase results in a complicated mathematical model, and the number of equations is 2^n.

A. S. Kytsyk, A. O .Lozynskiy, O. F. Kinchur

THE MATHEMATICAL MODEL OF SYSTEM “FREQUENCY-CONTROLLED ELECTRIC DRIVE – PUMP – WATER MAIN”

The electric drives of pumps and ventilators are one of the basic consumers of electric energy. The asynchronous frequency-controlled electric drive is mostly use to drive pumps. One of the actual tasks of a power efficiency increasing of a water supply systems there is a creation of new control algorithms for pumps' electric drive. It, in turn, requires the mathematical modelling of pumps' working regimes with taking into account the wide range of regime parameters variation and the real characteristics of water main.

The feature of the described in the article mathematical model of a system "frequency-controlled electric drive – pump – water main" is taking into account the non-linearity of a magnetization characteristic of asynchronous motor, the possible asymmetry of voltages in supply network, the distributed parameters of water main, the interference between a water main and a pump's drive. It distinguishes this model from the linearized models of the asynchronous frequency-controlled drive of pump with simplified presented asynchronous motor with ventilator character of loading.

In order to create the described model the object-oriented method is used. According to this method the model of the system is formed from typical elements, in particular: power supply networks, frequency converter, asynchronous motor with a short-circuit rotor, pump, water main. Model of every element, appears as an object, according to principles of the theory of object-oriented design.

By means of the developed mathematical model the such researches were carried out: the research of electromagnetic and electromechanics processes in the pump's electric drive; the research of processes in a water main during a flow changing, including taking into account the real day's chart of consumption changing. The quality of regulation of the basic coordinates in the automatic control system of pump's pressure has been researched. Also, the analysis of power efficiency of the asynchronous drive in case of the use of different frequency regulation laws is carried out.

V. Moroz, T. Borovets

DC MACHINE MODEL'S IMPROVEMENT FOR SimPowerSystems LIBRARY OF Simulink SIMULATION ENVIRONMENT

The analysis of electric drives using Simulink simulation environment and libraries SimPowerSystems allows you to automate the process of the controlled electromechanical systems. However, there is a need to improve the existing libraries of environment.

The standard model of DC electric machine of library SimPowerSystems is the element that need an improvement. The standard model of DC machine of library SimPowerSystems of mathematical application MATLAB includes the simplest model, that's:

- do not include non-linearity of the magnetization curve;
- eddy currents are not included in the frame according the skin-effect.

This model is correct for DC electric generator with laminated frame below the nominal voltage and is acceptable for the engine mode with a constant nominal excitation.

Solving the problem to improve the models of DC electric machine of SimPowerSystems divided into two stages:

1) Implementation of nonlinear dependence of EMF anchor excitation current. This nonlinearity can be approximated in two ways:

- When using the arc tangent that provides relative accuracy at 2-3%, which significantly exceeds the accuracy of manufacturing of DC electric machines and variation of parameters of industrial machines series, and provides the smoothest derivative of the magnetization curve.
- Using standard 1-D Lookup Table block from the main Simulink library that performs spline interpolation for the given points.

In the absence of passport data for electric machines for the implementation of the nonlinearity recommended to use universal magnetization curve.

2) The model for imitation of actions eddy currents in a massive frame of DC machines with the skin-effect is proposed. This version of excitation circuit is realized by replacement simple RL-branch in standard model by the proposed complicated equivalent circuit. Variant implement such a model is proposed taking into account the effect of eddy currents and skin-effect in the machine's frame.

Comparison of standard and improved models are made on the example of the generator type 4GPEM-220. The results correspond to the real system.

V. Moroz, I. Oleksiv, V. Tsyapa, G. Sivyakova

DYNAMICS ANALYSIS OF THE CROWD ELECTRIC DRIVE OF THE MINING EXCAVATOR EKG-10

The crowd drive is the fastest in view of the requirements for mining excavators digging mechanisms. The dynamic processes' study due to electromechanical processes' complexity without computer technology is almost impossible.

The part of excavators park equipped with thyristor exciter for generators type BUT the advantage of simplicity and exceptional reliability. To solve the problems of electric adjustment was done using computer simulation.

Research of the dynamics of the mining shovels' electric drives, held at the Department of electric drive "L'viv Polytechnic", showed that the traditional simplified models of the elements of automated electric drives do not provide real transients of excavators' drives because of the complexity of these systems.

To simplify the simulation of nonlinear crowd electric drive system can using the automation tool of the modeling process – simulation environment Simulink of MATLAB application with additional library SimPowerSystems, which made it possible to simplify and visualized process of creating the model of electric drive.

There if for the presence of eddy current circuit and for nonlinearity of the magnetization in the standard model proposed replacement of standard SimPowerSystems RL-circuit model to two-winding nonlinear transformer with the saturation magnetic system.

There is used refined model of the thyristor exciter type BUTV which takes into account the following significant features compared to traditional models:

- nonlinearity characteristics;
- consideration of voltage drop produced by commutation angle;
- simulation of logic block with inversion mode.

This advanced model BUTV as shown by experiments made it possible to really simulate the inverting mode and switching voltage drop. There are three functional parts in the structure of the thyristor exciter model:

- imitation of the adjusting characteristics;
- consideration of switching voltage's drop;
- logic simulation with invertor mode.

Start and reverse regimes of the full electric drive is researched using designed computer models. Recommendations based on the developed results proposed for adjusting electric control system.

A. Parfenyuk, P. Gogolyuk

REACTIVE POWER OPTIMIZATION OF ELECTRICAL POWER DISTRIBUTION SYSTEM CONSIDERING LOAD PROFILES OF POWER CONSUMERS

The objective of this paper is to create a method and algorithm to decide the optimal location and size of power capacitors for electrical power distribution systems with irregular loads.

The optimal reactive power planning problem is to determine the technical and economical characteristics of the electrical power system. In this thesis, the problem of reactive power compensation is first formulated with non-static loads of consumers that determining by load graphs.

The method to determine the number, capacity and location of power capacitors installations considering load profiles of power consumers is proposed. It made it possible to formalize procedures of selection of the type and mode of the reactive power compensation at the design stage of electric power distribution systems.

In order to solve the general problem, the objective function, systems *of constraints were* formed and optimization method was chosen. The objective function to determine energy losses of electric power distribution system takes into account the influence of reactive power controllers of power capacitors for irregular load profiles of electrical consumers. This makes it possible to simulate the activity of power capacitors at the operational stage, and to determine more accurately the power losses in electric power distribution system. The system *of constraints* includes the limits of voltage range variation of buses of electric power distribution system and desired value of power factor at the point of balance differentiation. To optimize the objective function in compliance with system of constrains a genetic algorithm was used. In order to ensure performance of genetic algorithm, the coding of types and locations of power capacitors was proposed and operations of crossing, mutation, selection of the genetic algorithm were formed.

Based on the language C++ a software implementation of the proposed method was carried out. Usage of developed software has shown an effective decision-making of the power, type and the installation places of power capacitors selection under condition of different configurations of electrical power distribution systems and load profiles of electrical consumers.

M. Solskyy

CONDITIONS OF REALIZATION DIGITAL REGULATORS ON DIGITAL CONTROL SYSTEMS WITH DATA FINITE PRECISION

Effects research that could cause incorrect work of digital control of actual electric drives is important.

One of the problems in the theory of digital control systems, that is, the problem of impact of finite-precision data on their behavior, is not enough investigated. The essence of the problem is that in the digital control system with finite-precision data decreasing of sampling step leads to the non-typical behavior of the obtained digital system deviating from continuity.

This problem explained by bad polynomials' conditionality of the numerator and denominator of discrete transfer function and the resulting displacement of all its zeros and poles to unity – the limits of stability of discrete n^{th} order systems.

The dependence between digit capacity of hardware of digital systems and minimal admissible sampling step analyzed in this article. Particular attention was paid to definition of limit values of the sensitivity of the polynomials roots of the discrete transfer functions to changes in their coefficients based on first and second order blocks. The basic mathematical equations of minimal admissible sampling step h to the largest system time constant T described.

We overview mathematical equations of minimal admissible sampling step h to the largest system time constant T into the list for 1^{st} order block with one real pole and 2^{nd} order block with pair of complex-conjugate poles for N-order digital systems, where N is binary or decimal bit of digital system.

Fundamental limit on minimal admissible sampling step in digital control systems with data finite-precision shown in this article. In digital control systems with data finite-precision should be considered the basic mathematical equations of minimal admissible sampling step h to the largest system time constant T to reduce the impact of data finite-precision in digital systems.

I. Shchur, I.Chupylo, Yu. Pavliv

THE SYSTEM OF TWO-ZONE SPEED CONTROL OF GEARLESS TRACTION ELECTRIC DRIVE FOR A LOW-FLOOR TRAM

This article proposed and investigated two-zone control system of traction direct electric drive for low-floor tram based on a specially developed multipolar synchronous motor with permanent magnets (PMSM). This system will provide the drive of one of the four trolley wheels of 5-section tram at real weight 55500 kg with three traction trolleys. Direct drive wheels of the tram makes it necessary to ensure the smooth electromagnetic torque of the drive motor. At the same time, the large size of the motor, the limited space to it install and difficult operating conditions do not allow the use of multipoint encoder needed to PMSM vector control. The peculiarity of the developed system of electric drive is that continuous electronic switching of PMSM armature windings that provides a vector control carried out according to the signals from the three discrete Hall sensors with optional built-in the motor magnetic information system. For this purpose applied a so-called hybrid observer, which allows you to calculate the value of the angular speed and position of the rotor angle and discretely adjusted them according to the signals from the Hall sensors. Using known principles of vector control of PMSM a simulation computer model of the proposed system was created and made its settings in the MATLAB/Simulink. To work the electric drive in the second zone of angular velocity control, the field weakening method by forming the value of direct component of armature current I_d, which required for the given speed and load torque, was applied. Model research of static characteristics of PMSM at work in the second zone speed control was carried out. Thus, at the angular velocity, which is 2 times the nominal, the motor provides a torque 1000 N·m, which is 85% of the rated motor torque. Dynamics of developed the electric drive system characterized by good performance, as evidenced by the model waveforms obtained of transients under the influence of perturbations on the reference and load in both the zones of speed control.

I. Shchur, O. Makarchuk, V. Shchur, P. Golubovskyy

ELECTROMAGNETIC HEAT GENERATOR FOR AUTONOMOUS VERTICAL AXIS WIND TURBINES

In order to reduce the cost of stand-alone vertical axis wind turbines (VAWT) and expand their functionality, it is advisable to accumulate wind energy as a heat. For this propose was developed special heat generator – electromagnetic transformer of mechanical energy into the heat (ETMEH). Cogeneration VAWT is equipped with two generators – electricity and heat. It has a quite many advantages over traditional stand-alone electric wind turbines with electrochemical batteries. Current wind turbine has high-energy effectiveness on all wind speeds, including higher than nominal wind speed, what is limited in traditional VAWTs by generator rated power. Using such approach it is possible to reduce (up to complete exclusion) installed capacity of electrochemical batteries, what allows reducing the cost of wind turbine. In addition, it reduces energy losses during generation of heat energy directly from mechanical energy, excluding intermediate electrical link.

In this article developed the method of calculation of relation between electromagnetic and thermal fields in ETMEH elements. Based on this method software in ANSYS is developed. It makes possible to hold a series of calculations to optimize the parameters of the proposed design heat generator. It was highlighted seven independent variant variables, which used for calculation of all the rest design parameters. For decrease of thermal time constant of ETMEH and its cost, total mass of magnetic elements selected as the optimization criteria. Based on calculations made mock model of ETMEH, with rated heat output of 500 W at 250 rpm rotor speed. Also created a stand with DC motor, which through the gearbox drives the unit with electrical and thermal generators. The investigation of created stand showed the satisfactory performance of ETMEH mock models derived from the calculations and physical experiment, what confirms the adequacy of the developed methods of mathematical modeling.