ABSTRACTS

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APPLICATION OF DIGITAL SYSTEMS TEST FOR VERIFICATION DISTANCE PROTECTION

When configuring a scheduled inspection and remote protection, special protection is performed on a digital basis, there are difficulties in ensuring technical means of verification. In particular, the traditional analog hardware can't provide appropriate accuracy and require significant time costs.

Currently abroad created tools for configuration and testing of relay protection and automation (RPA), as carried out in the analog and the digital principle. Preference is given to devices on a digital basis. These devices allow you to quickly and efficiently set up and perform a comprehensive test of the RPA devices, including distance protection.

The mathematical model of the electrical network, made its digital implementation and created digital module testing system for checking the optimal distance protection.

With the created module:

- Manages device;
- Set options for checking specific devices RZA, including distance protection;
- Generated in digital form to check relay device voltage and current signals are formed by a specific law;
- Given change in output binary signals;
- Displays test results RZA devices;
- Generated test protocols;
- Formed library facilities inspection.

Module test distance protection is designed to configure and test of remote protection of both foreign and domestic firms sold for electromechanical, semiconductor and digital technology.

Using this module allows you to test virtually all the characteristics of distance protection – zones triggering certain steps with regard to acceptable errors, the time characteristics of certain triggering levels, resistance to higher harmonic components, the reaction relay devices for various power system disturbances such as induction course and swing, as well as some other characteristics.

Z.M. Bakhor, O.V. Danyluk, B.I. Durniak, A.B. Kozovyj

FORECASTING OF LOADING OF ELECTRICAL POWER SYSTEM

During the management of the electrical power systems the modes the row of important tasks decides, one of which there is short-term prognostication of loading of the electrical power systems with passing from one days to week.

Development of models of prognostication of loading of the electrical power systems is an intricate problem, because the change of loading has casual character, depends on duration of light part of twenty-four hours, from meteorological factors: the temperatures of air, cloudiness, strengths of wind, that determine seasonal vibrations and day's unevenness of the load-graphs.

On results the analysis of retrospective data – sentinel rows of the daily allowance load-graphs of the electric stations of EEC it was necessary to work out a model for short-term prognostication of power

of loading of the electric stations of EEC taking into account meteorological factors with passing on twenty-four hours and to estimate exactness and reliability of results of prognosis.

In the manuscript of the article the model of prognostication is considered in that two is distinguished component loading: base and casual. These constituents, accordingly, take into account the a week's recurrence of loading, influence of duration of light part of twenty-four hours, and also meteorological factors (temperature of air and cloudiness). Detains for a model are day's graphic arts of loading of the electric stations of the electrical power systems and average value of temperature of air in a region.

B. Kharchyshyn, T. Dz'oba, O. Petrova, V. Khai

COMPENSATION OF FORCE RIPPLE IN A MODERNIZED LINEAR MOTOR

This article deals with the modernization of cylindrical two-phase linear motors with monocoil phases of pilots simulator load. We describe a way to modernize the linear motor in the specified dimensions to improve its initial efforts due to increasing the amount of copper by expanding coils. The size of fluctuations efforts that occur when changing the relative position of the coils axes phases was determined. We have found a way to compensate for fluctuations effort by using specially formulated law of changing the phase currents depending on the slider position. This law consists in corresponding switch of the phases commutation angle, contrary to the direction of coils extension. The optimum parameters of modernization in terms of maximum effort have been elaborated. Dependences of engine parameters on the value of additional width coil have been provided.

We calculated on how efforts can be increased in the case of two-phase motor when electromagnetic loads are constant, and what winding data changes should be imposed in linear motor ЛД/С3Т45-2 for optimal coils phases expansion with pulsation compensated effort.

The results of the experiments have been provided- the efforts of the upgraded engine have increased by 9 percent at constant value of its pulsations. We demonstratedaaa graphical charts of flux windings, phase currents and total efforts of the modified engine.

L.J. Glukhivskyj

TO THE QUESTION OF CALCULATION OF TRANSIENTS IN NONLINEAR ELECTRIC CIRCUITS BY A DIFFERENTIAL HARMONIC METHOD

The possibility of application of differential harmonical method (DGM) for the numerical calculation of transients in nonlinear electric circuits with periodic electromotive force is probed in this article. In the past this method was developed by the author of this article for the numerical analysis of periodic processes in nonlinear electric circuits and devices.

Essence of method is replacement of variables: the instantaneous variables (currents, voltages, magnetic fluxes etc.) are replaced other variables – the amplitudes of harmonics of the Fourier series, which are the functions of time in transients. Thus every scalar instantaneous variable is answered by a vector, named the vector of amplitudes, the components of which are amplitudes of harmonics of dependences on time of scalar instantaneous variables.

At such replacement of variables there is a transition from differential equations for instantaneous variables to differential equations for vectors of amplitudes. These equations are named differential DGM-equations. DGM-equations that describe processes in nonlinear electric circuits are nonlinear. The amplitudes of the harmonics of all variables (elements of vector amplitudes of these variables) for all orders of harmonics are taken into account in the calculation are interrelated. To take account of this relationship suggested use of matrix differential harmonic parameters.

The values of the matrix of differential harmonic parameters and the values of the vectors of the amplitudes of all the dependent variables are calculated at each step in the numerical integration of nonlinear DGM-equations using the values of vectors of the amplitudes of the independent variables. For implementation of these operations in the programs of calculations of transients it is possible to use algorithms and procedures which can be found in the monograph the author of this article«Nonlinear oscillations: numerical polyharmonic simulation» (2008, bibliographic information can be found in the list of the quoted literature).

Applicability DGM-method to the calculation of transients in electrical circuits is illustrated on example of the R-L-C circuit, which have a nonlinear inductance with the magnetization curve in the form of analytical approximations or table.

Calculations have shown that in transients of this circuit dependences on the time of the amplitudes of harmonics are more calm and "quieter" than dependences on the time instantaneous variables. Therefore numerical integration of DGM-equations can be made with greater lenght of steps, than when differential equations for instantaneous variables are integrated with the same relative error. This feature is useful at a necessity the numerical calculation of transients real-time, and also when exists a problem of inflexibility of differential equations is for instantaneous variables.

P. F. Gogolyuk, T.M. Hrechyn, A. O. Parfenyuk

A SYNTHESIS OF THE POWER DISTRIBUTION SYSTEMS OF THE INDUSTRIAL OBJECTS ON THE BASIS OF METHODS OF DISCRETE OPTIMIZATION

Determining of the optimal location of the transformer substations establishing, distribution of loading between them, a search of optimal routes of the electric lines gasket is a basis to construct economically effective power distribution system of industrial object. Till now these project procedures do not have clear mathematical formulation and unambiguous algorithmic formalization under condition of the limited possibilities of computing facilities. Among project procedures of the operating technology used for planning of the power distribution systems they have the lowest automation level. It is predefined by essential complexity of the general optimization task of synthesis of chart of the power distribution system of industrial object because of the presence of discrete variables, that is determined by properties of the designed objects.

The goal of the research is a development of the effective method of synthesis of charts of the power distribution systems of industrial objects in order to increase the efficiency of functioning of intellectual CAD intended for planning of the power distribution systems.

Project procedures of intellectual CAD systems intended for planning of the power distribution systems are based on application of such algorithms of discrete optimization as branches and limits, dynamic programming, search on the graphs of A-star, Dijkstra's *algorithm* and heuristic methods. The program implementation of the intellectual CAD for planning of the power distribution systems using the C^{++} language was carried out.

Conclusion. An expediency and efficiency of application of the discrete optimization methods to improve the automated planning technology for the power distribution systems of industrial objects was shown. On the basis of their application an essential increasing of automation level of modern CAD intended for planning of the power distribution systems can be achieved. The possibility of gradual transition to development of high-efficiency intellectual CAD for planning of the power distribution systems considering the world tendencies is explained.

L.I. Demkiv

INVESTIGATION OF THE DEFUZZIFICATION METHOD INFLUENCE ON CHARACTERISTICS OF THE SYSTEM WITH TAKAGI-SUGENO FUZZY CONTROLLER

One of the possible approaches to the synthesis of electromechanical system's controller is application of the fuzzy set theory. This approach makes it possible to take into account nonlinearities and synthesize control influences for different points of the state space.

Traditionally, the most common defuzzification methods are center of average (COA) and mean of maximum (MOM) one of the possible modifications of which is method of average minimums. In the case of Mamdani type controller, there are several classical defuzzification methods – the first maximum, average maximum, the last maximum, center of gravity etc. And in case of Takagi-Sugeno type controller one usually uses a COA defuzzification method. Other approaches are not sufficiently investigated.

In this paper, a comparison between the classical approach and defuzzification which is usually applied in the case of Mamdani controller is help. Research is conducted on the example of two-mass system. The use of fuzzy set theory allows to synthesize control influences to ensure the formation of the system's trajectory as a combination of it's subsystems's trajectories with desirable characteristics. At controller synthesis only output error is fuzzified, and the other coordinates of the system state space are not.

One should note that the choice of a particular defuzzification method does not affect the behavior of the system under the influence of external disturbances and it is primarily determined by the switching sequence between the subsystems. Application of COA method, unlike max-defuzzification provides smooth switching between subsystems.

For some input-output models, particularly in the case of Takagi-Sugeno, choice of defuzzification is not essential because it can not significantly improve the dynamic characteristics of the system. Another situation one can observe when using Mamdani model where switchings can be quite large.

Obviously, the major disadvantage of MOM and min defuzzifications is abrupt switching between subsystems. Besides, the use of such defuzzification, as well as conventional variable structure systems may result in chattering effect that significantly affects the quality of the synthesized system. Most smooth switching is obtained by means of COA and BADD defuzzification with small parameter value. In all investigated defuzzification methods values of all coordinates varied according to the change of the control influence.

M. Mandzyuk, I. Shchyr

OPTIMUM CONTROL SYSTEM OF PMSM WITH FIELD WEAKENING BY VARIABLE VOLTAGE SUPPLY

To ensure a constant power mode in electric drive (ED) of vehicles and other mechanisms based on PMSM, there is necessarily to regulate the direct component of armature current i_d in the rotor axis frame *dq*, which weakens the machine field. Battery voltage in electric vehicle during operation may vary depending on the state of charge, temperature, wear and other factors. When using PMSM with the field weakening it is important to determine the point of transition from the first to the second zone, which depends on the supply voltage.

The modes of field weakening can be divided into four types: feed-forward control, feed-back control, hybrid control and control based on the theory of nonlinear systems. The system, which is developed in this paper, refers to the hybrid control type.

To determine the point of transition from the first to the second zone is generally used signal from the speed sensor or voltage sensor and the transition point to the second zone is determined on the basis of a mathematical model of PMSM. But this approach is sensitive to changes in the machine parameters. In this paper we proposed to use information about the states of the inverter keys to measure the voltage of PMSM. Oncoming of the relative width of control pulse of the voltage inverter to 1 means the inverter saturation and the need of moving into the second zone.

Control algorithm, based on this principle, works as follows. To reduce the ripple caused by PWM, the calculated relative value of the voltage signal is filtered. The maximum possible reference relative value of voltage $u_{\lim\_ pu}$ is subtracted from it. Their difference u_{sig} is sending to an integrator and forming Δi_d, correcting the part of reference signal i_d^*.

The computer model of ED based on PMSM with the vector control system and field weakening by the developed algorithm was created in Matlab/Simulink. The maximum mechanical characteristics of ED were obtained and the dynamics of control system was investigated for the values of DC voltage $U_{DC} = 240, 290, 340$ V.

A. Malinovski, E. Guschin, A. Niconec

MATHEMATICAL MODEL OF A NOM-10 VOLTAGE TRANSFORMER FOR FREQUENCIES OF THE FREE COMPONENT OF INTERNAL POWER SYSTEM OVERVOLTAGE

The phenomenon of internal resonance causes the necessity of changes in approaches to choosing of insulation of electrical equipment with high-voltage windings and methods of justification of rated overvoltage on its elements. Major overvoltages are not those that affect the electrical equipment from power system, but those that appear on elements of equipments insulation because of internal resonance. It follows the need to create mathematical models of electrical equipment which could adequately reproduce processes in equipment under influence of free component of internal overvoltages with frequencies 50 – 100000 Hz.

The considered object is a NOM-10 voltage transformer, which has an additional (handmade) lead from the middle of the high-voltage winding, what allows to study the processes inside the transformer

winding, between the winding and the ground (ground insulation) and between two winding leads B1 and B2 (longitudinal insulation).

The mathematical model of a NOM-10 voltage transformer consists of two-terminals, which represent the interconnection between the main transformer parts (winding leads, tank), and the magnetic system model. The structure and the parameters of the two-terminals are defined using experimental frequency characteristics of the relative elements.

Criterion of the mathematical model adequacy is the correspondence of the frequency characteristics of the model elements and the frequency characteristics of the real object elements.

For frequency characteristics estimation, some special test schemes have been designed, each of them contains a minimum amount of two-terminals in action. Low-frequency generator with rated voltage 100 V was used in the tests as the power source with frequencies 50–100000 Hz. Depending the nature of frequency characteristics different types of software were used to synthesize the electrical equivalents for corresponding element.

Two-terminals representing the parts of high-voltage and low-voltage windings have the resonance character and are modelled using series sections of parallel-connected R, C, and L elements. The rest of the two-terminals have capacitive character and is modelled using only capacitance C.

There is a magnetic interconnection through the magnetic core, between the two-terminals of the parts of the high- and low-voltage transformer windings, its voltage-current characteristic is defined experimentally for the voltages from 0 to the rated value (10 kV).

A.A. Malinovskyi, O.L. Nykonets, N.H. Maltseva, M.Y. Oliynyk

ELECTROMAGNETIC PROCESSES IN POWER TRANSFORMER WINDINGS DURING TYPICAL PULSE TESTING

Failure of power transformers is mainly caused by the action of switching and lighting overvoltages. Frequently under these conditions the interturn insulation is damaged. According to the authors suggestions the appearing of the resonant overvoltages can be the main reason of interturn insulation damage.

The goal of the research is to reveal the dangerous coordinates of the electromagnetic transient modes in the transformer windings during typical pulse tests.

To reveal the range of the resonant frequencies and dangerous areas of the transformer windings the researches of the power transformer overvoltages were carried out. Researches were conducted using the computer simulation methods based on improved model of the transformer under research. The simulation of the transformer operation when typical test impulses were applied was conducted. The features of the processes during the appearing of fluctuations of the voltage of the resonant character in the high voltage winding was shown. The frequency of these processes depends on the type of the test impulse.

The values of the resonant frequencies obtained during the mathematical experiment are in correlation with the results obtained when the physical experiment was carried out using the same transformer.

Conclusions. 1 When the pulse overvoltage is applied to the transformer winding the voltage resonance with one of possible resonant frequencies can appear. Amplitudes of free oscillations during such mode are commensurable with the applied pulse amplitudes. Duration of oscillations is higher in no less than ten times comparing with the pulse duration. These overvoltages can cause the interturn short circuits.

2. The main means to increase the power transformer reliability is to use high-voltage surge arrestors in all networks up to 110 kV.

3. It is necessary to conduct the researches of the most widely used transformers constructions in order to reveal the ranges of the resonant frequencies and dangerous areas of the transformer windings where the insulation should be strengthened.

A.V. Malyar, A.S. Andreishyn

DYNAMIC AND STATIC MODES OF ELECTRIC DRIVE OF ROD DEEP-WELL PUMPING UNITS

Sucker rod oil pumps are used for producing oil in most Ukrainian oil fields. The major way of ensuring trouble-free operation and enhancing oil production efficiency is computer control of the work of each pumping unit on the basis of reliable algorithms. Particularities of oil pumping unit electric drive include considerable inertia of the moving mass, variable moment of inertia and cyclical law of load moment change. As a result, processes in the electric drives of oil pumping units are dynamic both in the starter modes and in the stationary ones. Taking into account the wide range of change of crank counterbalance oscillation frequency, it is important to determine which of the operation modes can be regarded as quasi-static, and for which such an assumption results in significant errors. This problem has a big practical value, since the analysis of dynamic modes of oil-pumping unit operation requires applying quite complicated mathematical models, and if the problem is treated as static, the unit operation can be controlled using simple mathematical models.

The paper solves the problem of determining for what rotary speed of the crankshaft static equations are applicable and in what cases such an assumption causes serious errors, and dynamic equations should be used instead. It is proposed that a decision on the applicability of static equations should be made on the basis of standard deviation between the load moment and electromagnetic torque. The paper offers dependence of standard deviation in percents on the rotary speed of the crankshaft for the normal mode of the unit operation. This dependence is proposed for determining the applicability of static equation in the control algorithm to analyse the work of the oil pumping unit.

V.S. Maliar, I.R. Havdo

THE HARMONIC FIELD EFFECTS IN SHADED-POLE INDUCTION MOTOR

Despite its simplicity of construction, the shaded-pole induction motor (SPIM) is a difficult object for a theoretical analysis, because to this motor peculiar electric and magnetic asymmetric and considerable saturation of separate areas of iron core. Electric asymmetric of SPIM is due to a different number of turns, various cross-sections of turns of main winding and shading coil, by displacement of stators winding on a space angle less than 90 electric degrees, magnetic – predefined salient poles of stator core. Therefore the form of spatial distribution of magnetic induction curve in an air gap considerably differs from a sinusoid.

A mathematical model of SPIM and digital calculation of steady-states is described. The saturation of main magnetic flux is taken into account. The electromagnetic parameters are calculated on the base of ramified equivalent circuit of motor magnetic circuit. For the analysis, a d-q model of a generalized machine theory with two stator windings arranged in an arbitrary way in the stator is chosen. The

conversion of the sguirrel-cage rotor into a equivalent two-phase winding is possible. It allows to work out four equations of the electric state. The mathematical model of SPIM allows to expect steady-states modes in this motor at non-linearity of descriptions of magnetizing of core and arbitrary time-history currents of winding and magnetic flux.

The differential harmonic method to calculation steady-states in SPIM has been considered. The problem is solved using a nonlinear programming technique. The way of problem solving when the slip are given is shown.

The offered mathematical model allows to get the integral distribution of magnetic field in the air gap of SPIM for any value of slip from s=0 to s=1 and to get its harmonic analysis.

The got distribution of magnetic field in the air gap of SPIM for starting mode, the critical slip and at the nominal loading. For these modes data of harmonic analysis of curves of the field $B\delta = f(\alpha)$ – absolute and relative values of main and high harmonics (3, 5, 7) are got. At the calculation of relative values of high harmonics for "unit" there is the accepted amplitude of the first harmonic.

Executed a harmonic analysis is confirmed by the improvement of curve of the field of SPIM in the nominal mode by comparison to the starting mode and with work at the critical slip.

V. S. Malyar,. I.A. Dobushovska

TRANSIENT PROCESSES IN ASYNCHRONOUS ELECTRIC DRIVE WITH INDIVIDUAL REACTIVE POWER COMPENSATION IN CASE OF LOSS OF SUPPLY VOLTAGE

The article discusses the problem of calculation of transient processes in asynchronous motors that work with switched in parallel capacitors in case of loss of supply voltage. The basis of the algorithm is a mathematical model of asynchronous motor that includes magnetic saturation of motor as the main magnetic flow and the flow dispersion, and current extrusion in the bars of the rotor.

Researching the dynamics of processes uses three-phase coordinate system in which the stator winding is not converted, and the rotor winding is changed to a three-phase fixed, so that the equations of electric balance include electromotive force caused rotor rotations. Taking into consideration saturation the mathematical model of the motor uses magnetization curves of the main magnetic flow, dispersion flows of stator winding, dispersion flows of rotor winding including flows closed through gear teeth, which leads to saturation. Taking into consideration current extrusion in the bars of the rotor is made through partition into n parts by height, as a result mathematical model of the motor considers mutually fixed windings: three-phase stator winding and n three-phase rotor windings. Calculation of transient process is realized by numeric integration of system of differential equations composed by Kirchhoff's laws for loops of the stator and rotor having mutual inductive communications, and equations of the rotor dynamics. The elements of the Jacobi matrix of the system is a full matrix of self- and mutual differential inductances of the loops of the system, which are based on the corresponding magnetization curves.

Designed algorithm and based on it program for calculation processes in system asynchronous motor – capacitors gives an opportunity to investigate the dynamics of the processes in case of loss of supply voltage with different values of capacitance of capacitors. It should be used for validation of the selected from static characteristic value of capacitance of capacitor in dynamic modes, as in this case overvoltages can appear caused by resonance phenomenon and self excitation.

***Key words**: asynchronous motor, transient processes, capacitive compensation*

Ya.Yu. Maryshchak, B.L. Kopchak, L.S. Kopchak

FRACTIONAL ORDER CONTROLLER IN THE FRAMEWORK OF SLAVE VOLTAGE REGULATION OF AUTONOMOUS INDUCTION GENERATOR

Problems of voltage control of wind turbines with induction generator (IG) and thyristor compensators of reactive power (TKRP) are associated with nonlinearities of magnetization IG, the presence of self-excitation capacitors, etc. Such a system can be attributed to the class of systems described by differential equations of fractional order. Therefore, the creation of autonomous control systems for wind turbines with IG using fractional order regulators and the development of methods of their choice present urgent problems.

The purpose of the article is to develop and study the block diagram of the control system autonomous turbines with IG and TKRP on the condition of the desired static and dynamic characteristics of fractional order controllers. Such automatic control systems (SAC) should provide high accuracy and IG voltage regulation speed, enabling its work without additional power supply and reliability.

We have proposed SAC of self-excitation IG voltage with the usage of TKRP, which is implemented as a double slave control system, by entering the inner current control loop R_K,L_K – TKRP load.

The research was conducted by means of mathematical simulation in MATLAB Simulink environment. Linearized model of hypertension, as an object of regulation, with P_N = 55kW, $U_{F.N}$ = 220V, $I_{F.N}$ = 106A was used.

The basic version of the system under the study was synthesized by the method of generalized characteristic polynomial. The analysis of the results reveals that the change of settings of the integral component of TKRP current regulator significantly affects the shape of the output voltage, as well as the change of the parameters of the integral component of the TKRP voltage regulator significantly affects the amplitude and the period of IG output voltage.

The results of the research have demonstrated the prospects for the application of PI regulator of fractional order for the slave voltage regulation system of the voltage of autonomous IG with TKRP. The proposed voltage regulator (VR) of fractional order has provided a transition process with the overshoot on the level of modular optimum, and thus, four times higher performance with the action of disturbance, compared with the classic PI -VR. The results of the research have revealed promising application of the proposed fractional order voltage regulator in SACS of voltage of autonomous induction generators.

Ya.M. Matviychuk

MACROMODEL INDUCTION MOTOR ON EXPERIMENTAL DATA

Experimental transfer characteristics of three-phase motor A051-4A, Pw = 4.5 kW, voltage 220V. Induction motor is presented "black box." Input signal - moment of mechanical load on the motor shaft *S*. Output signals - a supply current of one of the phases *I* and rotor speed *W*.

Macromodel is created for RMS current *Is* and the average over the period 0.02 sec values speed *Ws*. Macromodel equations is two differential equations for state variables *Is* and *Ws*:

$$dIs/dt=K_{I1}+K_{I2}*S+K_{I3}*Is+K_{I4}*S^2+K_{I5}*S*Is+K_{I6}*Is^2+K_{I7}*Is^3+K_{I8}*Is^4+K_{I9}*Is^5;$$

$$dWs/dt=K_{W1}+K_{W2}*S+K_{W3}*Ws+K_{W4}*S^2+K_{W5}*S*Ws+K_{W6}*Ws^2+K_{W7}*Ws^3+K_{W8}*Ws^4+K_{W9}*Ws^5. \quad (1)$$

Identification macromodel (1) is a minimum mean-square residuals of equations (1) at all time points t_i [1]:

$$\min_{K_I} \sum_{i=1}^{357} (dIs(t_i)/dt - \sum_{j=1}^{9} K_{Ij} * S(t_i)^m * Is(t_i)^n)^2;$$

$$\min_{K_W} \sum_{i=1}^{357} (dWs(t_i)/dt - \sum_{j=1}^{9} K_{Wj} * S(t_i)^m * Ws(t_i)^n)^2. \quad (2)$$

To solve problem (2), except $S(t_i)$, $Is(t_i)$, $Ws(t_i)$ must have $dIs(t_i)/dt$ and $dWs(t_i)/dt$. At 357 values of $Is(t_i)$, $Ws(t_i)$ constructed a cubic smoothing splines. Derivative $dIs(t_i)/dt$ and $dWs(t_i)/dt$ found analytically splines differentiating.

Problems (2) are simple, for their successful solution does not require regularization. Found 18 factors substituted in the macromodel differential equation (1).

Solutions of equations (1) is well consistent with the experimental signals *Is* and *Ws*. Rms relative errors is less than 1%.

Macromodel induction motor is very simple and satisfactorily reproduces the experimental transient response. However macromodel with other input and output signals must identify all repeat again.

Applications are available at the author e-mail matv@ua.fm.

L. Niconec, E. Guschin, P. Klimuk

EVALUATION OF THE MATHEMATICAL MODELS ADEQUACY OF NOM-10 VOLTAGE TRANSFORMER FOR THE FREQUENCIES OF THE FREE COMPONENT OF THE POWER SYSTEM INTERNAL OVERVOLTAGE

The phenomenon of internal resonance under the influence of power system overvoltage is one of the main causes of transformers damages. The only way to study this phenomenon is to use mathematical modeling. This provides creating of electrical equipment models, which can recreate real physical processes under the influence of the overvoltage free component of different frequencies. Thus, the received results validity and specific recommendations for increasing working reliability of electrical equipment depend on the degree of mathematical model adequacy.

The considered object is a mathematical model of NOM-10 voltage transformer, which was created taking into account its real frequency characteristics. The model reproduces processes in voltage transformer, which is under the influence of the overvoltage free component of frequencies 50-100000 Hz.

Criterion of the mathematical model adequacy is the matching of frequency characteristics of the model elements with the frequency characteristics of the real object elements.

The comparison of frequency characteristics of model windings and insulation with data obtained experimentally reveals their absolute identity, which confirms the model adequacy.

Complex model assessment requires comparing of research data for real object, which were not used in developing of model, with similar results, received on model. Frequency characteristics, which were received from those additional experiments on the real object and its model, match as well, which proves the adequacy of designed mathematical model.

Y. Romaniuk, O. Solomchak, A. Solomchak

CHOOSING THE OPTIMAL LOCATION OF DISTRIBUTION SUBSTATIONS (SWITCHGEAR) IN NETWORKS OF POWER SUPPLY COMPANIES CONSIDERING EXTERNAL POWER LINES.

The method of choice of the optimal location of the main power distribution substations (DS) , switchgear (SG), power supply companies considering external power lines has been offered.

Choice of the best location of distribution network is carried out by a combined criterion of discounted profits of the company that takes into account the costs of construction and operation of transmission lines.

Similar expressions to identify the location coordinates of DS (SG) with and without taking into account external power lines that corresponds to the maximum discounted profit were obtained. It is shown that for the same nominal voltage distribution network and the external power line SG, the optimal placement of the SG is at the point that is substantially displaced relatively to the center of the electrical loads in the direction of the power supply (main substation). If the voltage external power line is chosen to be higher than the selected nominal voltage of distribution network, the coordinates of DS are almost identical with the center of electrical loads.

The choice of the ultimate supply scheme of distribution substations of power supply networks should be performed on the basis of technical and economic comparison of options of schemes and all the costs for construction of main power distribution substations (DS) , switchgear (SG), and transmission lines should be considered..

The technique can be used for the design and reconstruction of electrical distribution networks of electricity supply companies and enterprises.

V.I. Tkachuk, I.E. Biljakovskyy, L.V. Kasha, I.G. Shapovalov

EXPLICIT-POLE BRUSH-LESS GENERATOR WITH U-SIMILAR STATOR

Last few years, in modern electromechanics converter (EMC), both in motors and in generators with limited power, excitation from high-energy permanent magnets (PM) is applied all more often. A number of structural, technical and field-perfomance advantages of such EMC facilitated production increase.

Some electrical drives on the base of brush-less direct current motor were developed on the department of electric machines and apparatus in Lviv Polytechnic National University.

Amidst known constructions of stator magnetic circuits of electromechanics converter of BLDM, U-similar and pseudo-U-similar stator construction were mainly used as most rational from technology viewpoint. That construction can provide the best dynamic indexes for less inductance of dispersion and rotor reaction as a result of practically complete magnetic isolation of phases, and as a result - have more advantages [1]. However, a tooth numbers of stator in such engines must be large enough, that can profit at the use of them for EMC with relatively low speed and with large diameters.

Magnetic circuits and not identical ways of working magnetic flux, predetermine the necessity of creation of design techniques of EMC for generators, as well as for motor, which accordingly, some differ. The calculation of the magnetic system of such generator with sufficient exactness can be carried out, like, as well as engine [1], with taking into account on the initial stage only major influences.

The calculation of generator with permanent magnets consists of two parts: determination of basic sizes and checking calculation. Unlike methodologies of calculation of basic sizes of the known types of

electric machines that are based on the choice of the electromagnetic loading coming from design experience, for a generator with PM on a rotor and with U-similar stator such experience is limited to.

As theoretical and experimental researches shows - relative by the geometrical sizes of tooth-pole zone of EMC for generator with modern magnets are approximately in the same limits, as well as for EMC of motors [1]. In particular, optimal values of coefficient of stator pole overlap are in limits, and coefficient of rotor pole overlap of generator - in limits.

It is possible taken into account the real distribution of magneto-motive force (MMF) on the height of PM for clarification of dissipated conductance values of PM. Distribution of MMF and magnet's dispersion fluxes can be found for a concrete construction from the decision of differential equalizations of magnetic-field by numerical methods with the help of computer. After determination of necessary maximal flux, width and length of permanent magnet, the diameter of inductor can was chosen.

Depending on the necessary area of the transversal crossing of section coil, size of U-similar elements of stator magnetic circuit are determined by the known methodologies. After pre-selection of rotor diameter, on methodology [1] specify the got values of basic sizes and in case of substantial divergence with set, repeat calculations from specified data.

Given over theoretic estimations and correlations is the methodologies of project calculation of basic geometrical sizes of generators with PM and U-similar stator construction. Results of researches of such generator, which was designed with the use of given methodology, affirm the sufficient level of adequacy.

B. Kharchyshyn, T. Dz’oba, O. Petrova, V. Khai

COMPENSATION OF FORCE RIPPLE I N A MODERNIZED LINEAR MOTOR/

This article deals with the modernization of cylindrical two-phase linear motors with monocoil phases of pilots simulator load. We describe a way to modernize the linear motor in the specified dimensions to improve its initial efforts due to increasing the amount of copper by expanding coils. The size of fluctuations efforts that occur when changing the relative position of the coils axes phases was determined. We have found a way to compensate for fluctuations effort by using specially formulated law of changing the phase currents depending on the slider position. This law consists in corresponding switch of the phases commutation angle, contrary to the direction of coils extension. The optimum parameters of modernization in terms of maximum effort have been elaborated. Dependences of engine parameters on the value of additional width coil have been provided.

We calculated on how efforts can be increased in the case of two-phase motor when electromagnetic loads are constant, and what winding data changes should be imposed in linear motor ЛД/С3Т45-2 for optimal coils phases expansion with pulsation compensated effort.

The results of the experiments have been provided- the efforts of the upgraded engine have increased by 9 percent at constant value of its pulsations. We demonstratedaaa graphical charts of flux windings, phase currents and total efforts of the modified engine.

Serhiy Shcherbovskykh

MATHEMATICAL RELIABILITY MODEL FOR MINIMAL CUT SET ANALYSIS OF ELECTRICAL SYSTEM WITH WHOLE STANDBY REDUNDANCY

In this paper the mathematical reliability model of repairable electrical system with whole standby redundancy for determination cut set probability indexes is proposed. Cut set probability indexes are used for down state courses analysis and for creating recommendation for system reliability improving. The system is composed of three components: generator, converter, and storage battery. The generator and the converter are made up the main subsystem, and the storage battery is made up reserve subsystem. The reliability of such system is formalized by dynamic fault tree. System down state is occurred if both main and reserve subsystems are in down state. Main system down state is occurred if even generator or converter is in down state. Reserve system down state is occurred if storage battery is discharged or faulted. Time to failure for all components is distributed by Weibull and repairing time for system is distributed by exponentially. Dynamic reliability behaviors are proposed to define by scale function. For proposed reliability model such function are used for description of two coupled change load event. The first event consists in operational component of main subsystem turn off if other one is faulted. And the second events consist in reserve subsystem turn on if main subsystem is faulted. Based on dynamic fault tree the state and events model of system is formed. Such system includes five states, three of which are operational. Six events can occur in the system, two of which are failures. Using states and events model is constructed split homogeneous Markov model of system. In such model states are split into 40 phases and events split into 48 transitions. By split homogeneous Markov model is defined probability indexes of both cuts and they important order is recognized. The main advantage of proposed mathematical reliability model of electrical system with whole standby redundancy consists in treating of load changes impact on cut probability indexes.

A. Yatseyko, K. Kozak

INFLUENCE OF THE MODE OF NEUTRAL OF THE ELECTRIC SYSTEM OF 6–35 KV IS AT THE LEVEL OF INTERNAL OVERSTRAINS

The electric networks of 6-35 kV can work in the mode with isolated, resistive - and the resonantly-grounded neutral. At the same time, in a scientific environment there is not definite idea in relation to application of that or other method of neutral ground.

The most widespread reasons of emergency damages in these electric systems are arc and commutation overstrains, and also feroresonance processes.

The executed researches on the basis of digital design of influence of the mode of operations of neutral of the electric system of 6-35 kV on multipleness of internal overstrains allow to assert that the mode of operations of neutral influences at the level of arc and feroresonance overstrains and does not influence on the value of overstrains during commutations of electric motors. The most values of arc overstrains are observed in the electric systems with the insulated neutral. At a resonant neutral of considerable decline of sizes of arc overstrains ground it is possible to attain only for a case practically ideal resonant tuning.

Application of high-resistance neutral ground provides the considerable decline of levels of arc overstrains, practically to the values safe for the isolation of electrical equipment regardless of character of

burning of earthing arc and configuration of the electric system. Feroresonance processes arise up in the electric systems with the insulated neutral and result in damages first of all, measuring electromagnetic transformers of tension and terminators of overstrains nonlinear. The increase of the secondary loading of transformer of tension within the limits of class of exactness does not result in fading of feroresonance, and vice versa, results in the increase of sizes of overstrains.

Commutations of electric motors are accompanied by the overstrains of considerable sizes, that present a serious danger for the isolation of these electric machines that is made with the facilitated isolation. On the sizes of these overstrains influence: character of commutation, length and parameters of nourishing cable, type of engine, him secondary loading and mode of operations of the electric system.

M.A. Yatsun, A.M. Yatsun

VECTOR POTENTIAL OF A MAGNETIC FIELD OF A FEED-THROUGH EDDY CURRENT PRIMARY RING TRANSDUCER OF A PARAMETRICAL TYPE AND A TRANSFORMER TYPE THAT ARE LOCATED IN A CONDUCTIVE PIPE.

Diagnosing of a technical condition of the trunk pipelines (gas pipelines) demand a determination of an actual thickness of a wall of the pipeline, detection of defects of type of infringement of integrity and definition of profile of its surface.

Eddy current method give the possibility to define the superficial cracks with small disclosing and the defects of stratification of the pipeline metal. If we are using an eddy current and a magnetic testing methods the primary transducer of a parametrical type or a transformer type usually have (can have) a form of the cylindrical coil with a rectangular shape of cross-section and is orientated (located) in alignment with a testing pipe. Therefore the actual is problem of calculation of a magnetic field a feed-through eddy current primary transducer of a parametrical and a transformer type that is located inside of a testing pipe the calculation model of which is show on fig. 1 where the following designations are accepted:

Accept such denotations: a_1 and b_1 – the sizes (width and height) of cross-section of an energizing coil; a_2 and b_2 – the sizes (width and height) of cross-section of a test coil in case of a transformer transducer; r_1 and r_2 – internal and external radiuses of an energizing coil; r_3 and r_4 – internal and external radiuses of a test coil; h_1 and h_2 – ordinates of a test coil; r_5, r_6 and d – internal and external radiuses and a thickness of a testing pipe; μ and γ – absolute magnetic permeability and specific electric conductance of a pipe; R and H – radius and height of the screen. We suppose that the areas into and outside of a pipe are not ferromagnetic ($\mu = \mu_0$ – permeability vacuum) and have specific electric conductance accordingly γ_1 and γ_3 .

Then Laplace transforming a vector potential of a magnetic field in cylindrical system of co-ordinates of r , α and z for all areas of research are define by expressions:

into a pipe

$$\tilde{A}_1 = \mu_0 \tilde{\delta}_{01} \sum_{i=1}^{\infty} \sum_{k=1}^{\infty} \frac{a_{i1} b_{k01}}{n_i^2 + m_k^2} J_1(n_i r) \cos m_k z, + \tilde{\delta}_{01} \sum_{k=1}^{\infty} [C_{11} \mathrm{I}_1(p_1 r) + C_{12} \mathrm{K}_1(p_1 r)] \cos m_k z;$$

in the body of pipe

$$\tilde{A}_2 = \tilde{\delta}_{01} \sum_{k=1}^{\infty} [C_{21} \mathrm{I}_1(p_2 r) + C_{22} \mathrm{K}_1(p_2 r)] \cos m_k z;$$

outside of pipe

$$\tilde{A}_3 = \tilde{\delta}_{01} \sum_{k=1}^{\infty} [C_{31} \mathrm{I}_1(p_3 r) + C_{32} \mathrm{K}_1(p_3 r)] \cos m_k z,$$

where $\tilde{\delta}_0 = \tilde{\delta}_{01}$ – the Laplace image of a density of current in a energizing coil of transducer; J_1 – Bessel's function of the first sort of the first order; $n_i = \lambda_i / R$; $\lambda_1, \lambda_2, ..., \lambda_i, ...$ – roots of the equation $J_1(\lambda) = 0$; I_1 i K_1 – modified of Bessel's cylindrical functions of the first order of the first and second sort; $p_1^2 = m_k^2 + p\gamma_1\mu_0$; $p_2^2 = m_k^2 + p\gamma\mu$; $p_3^2 = m_k^2 + p\gamma_3\mu_0$;

$$a_{i1} = \frac{2Y_1}{R^2 J_0^2(\lambda_i)}; \; Y_1 = \int_{r_1}^{r_2} J_1(n_i r) r dr;$$

J_0 – Bessel's function of the first sort of a zero order;

$$b_{k01} = \frac{4}{m_k H} \sin\frac{m_k b_1}{2}; \; m_k = (2k-1)\pi / H.$$

After disclosing of limiting and boundary conditions (15) for definition of unknown coefficients C with different indexes we will receive:

$$C_{11} = \frac{\mu N_1 P_1 \mathrm{I}_1(p_2 r_5) + \mu N_2 P_1 \mathrm{K}_1(p_2 r_5) - P_2 D_1}{P_2 \mathrm{I}_1(p_1 r_5)}; \quad C_{12} = 0; \quad C_{21} = \frac{\mu N_1 P_1}{P_2}; \quad C_{22} = \frac{\mu N_2 P_1}{P_2};$$

$$C_{31} = \frac{\mu P_1 \mathrm{K}_1(p_3 R)[N_1 \mathrm{I}_1(p_2 r_6) + N_2 \mathrm{K}_1(p_2 r_6)]}{P_2[\mathrm{I}_1(p_3 r_6)\mathrm{K}_1(p_3 R) - \mathrm{I}_1(p_3 R)\mathrm{K}_1(p_3 r_6)]};$$

$$C_{32} = -\frac{\mu P_1 \mathrm{I}_1(p_3 R)[N_1 \mathrm{I}_1(p_2 r_6) + N_2 \mathrm{K}_1(p_2 r_6)]}{P_2[\mathrm{I}_1(p_3 r_6)\mathrm{K}_1(p_3 R) - \mathrm{I}_1(p_3 R)\mathrm{K}_1(p_3 r_6)]},$$

where I_0 and K_0 – modified of Bessel's of a cylindrical functions of a zero order;

$$D_1 = \sum_{i=1}^{\infty} \frac{2Y_1 b_{k01} J_1(n_i r_5)}{R^2 J_0^2(\lambda_i)(n_i^2 + m_k^2)}; \quad D_2 = \sum_{i=1}^{\infty} \frac{2n_i Y_1 b_{k01} J_0(n_i r_5)}{R^2 J_0^2(\lambda_i)(n_i^2 + m_k^2)};$$

$$N_1 = \mu_0 p_2 M_1 \mathrm{K}_0(p_2 r_6) + \mu p_3 M_2 \mathrm{K}_1(p_2 r_6); \quad N_2 = \mu_0 p_2 M_1 \mathrm{I}_0(p_2 r_6) - \mu p_3 M_2 \mathrm{I}_1(p_2 r_6);$$

$$M_1 = \mathrm{I}_1(p_3 r_6) - \mathrm{I}_1(p_3 R)\mathrm{K}_1(p_3 r_6)/\mathrm{K}_1(p_3 R); \quad M_2 = \mathrm{I}_0(p_3 r_6) + \mathrm{I}_1(p_3 R)\mathrm{K}_0(p_3 r_6)/\mathrm{K}_1(p_3 R);$$

$$P_1 = D_2 \mathrm{I}_1(p_1 r_5) - p_1 D_1 \mathrm{I}_0(p_1 r_5);$$

$$P_2 = \mu_0 p_2 \mathrm{I}_1(p_1 r_5)[N_1 \mathrm{I}_0(p_2 r_5) - N_2 \mathrm{K}_0(p_2 r_5)] - \mu p_1 \mathrm{I}_0(p_1 r_5)[N_1 \mathrm{I}_1(p_2 r_5) + N_2 \mathrm{K}_1(p_2 r_5)].$$

The results that have received is expedient for use if define the own and mutual, the main and induced inductances of a feed-through eddy current primary transducer and their sensibilities to parameters and defects of testing research.

N.S. Ryabokon, V.V. Terehov, Y.M. Bohdanovskyy

GUIDING THE EXPERIMENTAL RESEARCHES OF ELECTROTECHNICAL MATERIALS WITH APPLYING OF DIGITAL VIDEO TECHNIQUE

Defining the issue, topicality

During the performance of researches in practice it is necessary to take into account the material's properties. Reference books provide an information on basic properties which could scientifically differ from the concrete materials. Material's composites could also differ from the one's mentioned in certificates.

Our practice witnesses that in some cases it is more reliable and simple to perform the measurement of separated material's properties and to apply those results in following work than to use data from reference books (input control).

Objectives of researches

Apply video technique for measurement of properties and composition of materials within a goal to achieve the lower prime cost, to simplify the researches, reliability of derived results and minimized participation of an operator in researches routine.

Exposition of core material

Digital video camera (DVC) allows to:

- exclude the influence of an operator from the process of measurement;
- fix processes in the mode of per-frame shoot with discreteness >= 1 sec for a long time;
- use in researches process the equipments that do not have an electro outlet signal;
- visualize the process of measurement;
- do not use PC for fixation of material's characteristics.

Considered an appliance of DVC in examples:

Determination of carbon level in steel and coefficient of linear thermic expansion (CLTE) in a temperature range of 50-900 °C.

Determination of tin-lead solder composition.

Determination of the exact capacity of condenser of high-capacity type.

Summaries

1) Created simple mount for dilatometrical discovery of steel. Using of DVC in per-frame mode of shooting allowed to avoid an involvement of skilled staff for tracking experimental dependencies and negative influence on reliability and accuracy of results. During processing of data were discovered temperatures of phase transitions and determined percentage of carbon in steel and CLTE both structural modifications of steel.

2) Determined a content of a specimen TIS (tin-lead solder) without an influence of operator. If a curve of chill is taken by PT-0102 and PC, then into PC automatically put data of temperature and time (in Escel). In that case DVC is not used.

3) Determination of volume of condenser with DVC lasts for 2 – 15 minutes. Experimental points can be fixed every second. This expands an interval of measurement of volume in field of relatively small volumes (~2 mcF). Durin an appliance of PT-0102 and PC data is automaticially taken into Excel and later on changed in values of U, I, q etc.

In shown examples in a hand mode (without appliance of DVC or PT-0102 and PC) is impossible to achieve trustworthy results.

DCV allows to apply simple tools for carrying experiments with a high reliability of the obtained results.