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CONCEPTUAL AND METHODOLOGICAL BASIS OF POWER EXPRESS EXAMINATION

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Abstract- The methodology of power express examination and the concept of the general theory of express examination of electrical calculations with the application of analytical models were developed. The proportionality coefficient express method based on the development of analytical models and an approximating approach was developed for carrying out power examination. The paper presents a holistic view of the methodological function of express examination for electrical engineering and energy facilities. The components of the methodology, issues related to the conceptual framework, specific features and the main trends of the development of power express examination are considered. A basic concept of an approximating approach and analytical modeling in reference to operational examination in power industry is provided. Basic features of functional analytical express models and a number of requirements to them are formulated; the choice of their type is justified. The authors draw the reasoned conclusion that the proposed express method makes it possible to receive required reliable numerical values of any electrical engineering parameters even in case of incomplete initial information.

Keywords: Concept, Methodology, Power Industry and Electrical Equipment, Express Examination, Solution of Expert Tasks.

I. INTRODUCTION

A. Relevance of Research

This applied research, which is carried out at the theoretical level, is conceptual; it develops the ideas of a new scientific direction of expertology developed by the authors – theory of electrical expertise [1, 2, 3, 9, 10]. Theory of electrical expertise is the general theory of electrical engineering examinations (GTE). The theory (GTE) includes a number of problems related to carrying out electrical engineering examinations and is a methodological base of the proposed research. One of the problems of the theory (GTE) is the problem of power express examination (PEE). This problem is a complex scientific task; it covers a considerable area of research and has a promising theoretical and practical value.

The problem of examination (PEE) consists of a number of subjects. One of these subjects, which is considered in the present work, is related to the development of the methodological bases of power express examination. The conceptual nature of the research is confirmed by the existence of several crucial ideas connecting the whole work, by integrated and systematic approach to studying the problem in all its aspects and interrelations.

The choice of the subject of the research was preceded by detailed studying of Russian and foreign sources concerning power and electrical engineering express examination. In the course of the research a vast amount of specialized scientific and technical literature was studied and summarized (more than 500 journal articles and books on electrical engineering and power industry). The authors also looked through numerous web sites, dealing with power and electrical engineering issues, and investigated the results of theoretical and applied research, directly or indirectly related to the topic of the study. In particular, the authors found out that there are only few researches on express examination [4, 5, 6], and there are no works on the express examination of electrical engineering calculations. This fact emphasizes the contradiction between the known and unknown knowledge; therefore, it makes the subject of research more relevant. In particular, we perform nonlinear modeling and analysis, controllers design, and validate the theoretical results.

B. Formulation of the Research Problem

The currently proposed approaches to the examination of the results of electrical engineering calculations are time-consuming and slow, which results in unreasonable time and financial expenditures, required for the development of expert decisions. This makes it impossible to quickly and reliably verify the calculated parameters of an electrical power system. In this regard, taking into account the above-mentioned contradiction between the known and unknown knowledge, the problem of the expert tasks solution, in particular, the problem of the development of the examination (PEE) methodology on a new conceptual basis is kept current.

The new conceptual basis is aimed at the improvement of quality and reliability of operational expert decisions by means of simple analytical models, which gives such concept theoretical and practical interest. In spite of the fact that the proposed concept is developed in view of the examination of electrical engineering decisions, its methodological orientation, undoubtedly, is relevant for any kind of examinations.

The problem of the operational solution of expert tasks results from the need for such tools in the expert practice, and it requires going beyond the limits of the available knowledge. This circumstance was the prerequisite of the given work, aimed at the solution of an important problem – the development of the scientific bases of power express examination.

C. Definition of the Research Direction

The direction of the scientific search depends on a problem choice. Proceeding from the formulated problem, we will determine the main areas of work – the development of a new methodology of express examination and a new express method within this methodology. Two criteria – the accuracy and speed of receiving the reliable result – have to be the main requirements when developing new methods. The specified directions determined the choice of the subject of the proposed research – the methodology of power express examination. The efficiency of the research in these directions is directly related to the relevance of the subject of research, which has never been developed in such an aspect, which makes it essentially new.

The economic aspects of the express examination of energy facilities and, in particular, elements of an electromechanical system (motor, converter, transmission and control devices) are not considered in the article.

- *The methodological basis of the research*

The methodological basis of the research includes the dialectic laws of scientific knowledge, and the general theory of examinations (expertology).

- *The theoretical basis of the research*

The theoretical basis of the research includes the conceptual researches on the general theory of electrical engineering examinations, carried out by the authors.

- *Methods of the research*:

The logical-linguistic (logical rules of making conclusions, developing proofs, etc.) and mathematical (mathematical models, methods of calculations, etc.).

- *Reliability of the research*

The reliability of the research is determined by:

1) Methodological justification of initial positions and theoretical concepts.
2) Integrated approach to the solution of the set problem.
3) Testing the correctness of each new analytical express model.
4) Full coincidence of calculation results, obtained using the conventional methods, and the results, obtained using the proportionality coefficient express method (PCEM).
5) Adequateness of the new method of examination (PEE) to the object, purpose, tasks and logic of research.
6) Diversity and a large number of the information sources, on which the conclusions are based.

D. The Idea of the Research

The boundary between knowledge and ignorance of the research object is determined by the methods of carrying out the examination of electrical calculations. This fact makes it possible to provide an accurate and unambiguous definition of the scientific problem of providing a reliable and fast express examination method, and, therefore, to formulate its idea. The idea of the research is reflected in the title of the article, and it implies that the authors evaluated the procedure of carrying out examination (PEE) from a new perspective, proceeding from a new conceptual basis, new theoretical views. For this purpose the known quantitative relationships between electrical parameters were generalized. These proportions were applied to known electrical engineering formulas by means of algebraic transformations. As a result, more than six hundred new analytical models consisting of the 2 … 6 parameters were obtained.

It is known that the express examination method is used for the purpose of receiving objective information on the correctness of calculation results in any branch of knowledge. A number of simple and thoroughly tested models, obtained by the authors, made it possible to carry out examination (PEE) without using complex and expensive calculation computer applied programs.

For carrying out examination (PEE), the basis in the form of specific methodology is necessary. Among the known [7] levels of methodological research (philosophical, general scientific, specific and scientific, technological) we will consider only the specific and scientific level of methodology, the aspects of which will be described below. Hereinafter the term "methodology" will be understood as the methodology which is carried out at the specific and scientific level of research in relation to carrying out the power express examination.

According to the definition, provided by the authors, the following definition of methodology should be given in relation to examination (PEE). Methodology is the basis of cognitive process for any specific scientific discipline in the field of power engineering, and also the tool describing the express examination problem, which:

1) Contributes to the reliability of examination (PEE).
2) Characterizes and theoretically proves the following main components of examination (PEE):

- Object, subject, purpose, tasks, principles, methods (approaches, techniques, methods, operations);
- Conceptual framework, specific features, main directions.

In a narrow sense it is possible to define the methodology of examination (PEE) as a theory of the essence and the content of on-the-spot examination methods taking into account the features of their application for specific objects.

- *The object of the research*

The object of research are electrical engineering calculations of the elements of an electrical power system (EPS), which will be presented to an expert for carrying out examination.

- *The research subject*

The research subject is the method of on the spot examination of the quality of the results of electrical engineering calculations of the parameters of the elements of a system (EPS).

E. The Purpose and Objectives of the Study

On the basis of the identified need for the solution of the above-mentioned scientific problem and for carrying out the offered scientific research, the objective (as a product of such a need) and the tasks of the work are determined. The objective of the research is the development of new knowledge in the form of the methodology of the examination of electrical engineering calculations (PEE) for increasing the productivity and efficiency of expert research. The formulated objective is related to an important scientific and practical direction – the increase of reliability and quality of expert decisions in power industry and electrical engineering.

To reach the stated objectives, it is necessary to solve the following tasks, reflecting various aspects of the problem and the object of the research, and corresponding to more specific purposes (for the achievement of the main objective):

- To find out the basic concepts of the methodology of examination (PEE);
- To reveal the essence of the approximating approach and analytical modeling;
- To give a general characteristic of the new method (PCEM);
- To give an idea of a conceptual framework, specific features and the main directions of examination (PEE);
- To draw the conclusions, based on the results of the research.

The objective and tasks of the research are indissolubly related to the subject, object and conditions (methods, techniques) of the research. The above-mentioned tasks offer a specific way of realizing new ideas and point of views, reveal the list of structural elements of the research, the sequence of carrying out the research.

- *Principles of the research*

Principles of the research: responsibility, independence and professional competence of an expert as a subject of examination; objectivity; single act of examination; consistency of researches.

- *Research methods*

During the development of methodology and the express method the following methods were used: general scientific methods of system analysis and synthesis; approximating, formal and logical, comparative, expert methods; an analogy method; inductive and deductive methods; methods of theoretical and logical analysis; an analytical modeling method; methods of generalization, abstraction and mental experiment.

II. BASIC CONCEPTS OF THE METHODOLOGY OF EXPRESS EXAMINATION IN POWER ENGINEERING

The methodology determines the characteristics of the research object, the tasks (problems) of the research and the research tools for the solution of these tasks (problems).

- *The purpose of the methodology of examination (PEE)*

The purpose of the methodology of examination (PEE) is carrying out methodical express examination according to the accepted rules with receiving specific results.

- *Place of the methodology of examination*

Defining the place of the methodology of examination (PEE), it should be noted that the methodology of examination (PEE) is the part of methodology of the theory (GTE). At the same time, the basic concepts of the methodology of the theory (GTE) aren't transferred mechanically to the level of the methodology of examination (PEE), but it is interpreted in detail.

Features of methodology of examination (PEE) are: reliability, specificity, completeness of the description of processes using analytical models, verifiability.

Regularities of examination (PEE):

- Uniform methodological features of functioning of different types of power examinations;
- Mathematization of examination, which accelerates the process of obtaining an expert report;
- Receiving the reliable scientific knowledge on the basis of available initial information; express examination can be carried out on the basis of incomplete initial information;
- Object designing of express techniques for carrying out on-the-spot examination.

Regularities form a basis for developing principles, concepts, rules; an indicator of regularity of any connection between elements of a system of any kind is the cause and effect nature of this connection.

- *Functions of examination* (PEE)

Control and test, analytical, estimating, diagnostic, predictive, and methodological. Functions of examination (PEE) are understood as various types of the tasks solved by means of on-the-spot examination. Implementation of the functions of examination (PEE) is a necessary condition for the achievement of the main objective of the theory (GTE) which is the prevention of low-quality electrical engineering decisions and negative consequences resulting from it. The offered work gives an idea of the methodological function of examination (PEE). This methodological function ensures correct understanding of the connection of the methodology of examination (PEE) with the methodology of the theory (GTE) and general methodology (materialist dialectics), understanding of the subject, contents and essence of examination (PEE), the strategy of expert tasks solution.

As the offered research is aimed at the development of the methodology of the scientific research, having some obligatory components, such as the object, the subject, the objective, tasks, principles, research methods, it is possible to assume that the components described

above have the same contents for the methodology of examination (PEE). In this regard, further in the article we will consider other components of the methodology of examination (PEE) – a conceptual framework, specific features and the main directions of the development. But first let us overview a number of the main concepts related to examination (PEE) – an approximating approach, analytical modeling and the proportionality coefficient express method.

III. GENERAL CONCEPTS OF AN APPROXIMATING APPROACH

Approximation is a scientific method, by means of which some mathematical objects (for example, numbers or functions) are replaced with the others, which are simpler, more convenient for calculation, but at the same time are close to the initial ones. Thus, approximation makes it possible to study easily calculated numerical characteristics and qualitative properties of an object. If the exact algorithms for the solution of a specific task require a lot of time for calculation, approximating algorithms are applied for the purpose of time saving. The concept of an approximating algorithm was first formalized in 1972. By means of approximation it is possible to receive the solution differing from the optimum within the limits of ±5%.

The essence of an approximating approach consists in the approximate description of correlation dependence of variables by a suitable equation of functional dependence. Such equation reflects the main tendency of dependence or a trend. In scientific developments approximation makes it possible to carry out description, analysis and generalization with the use of empirical formulas, to replace complex objects of research with simpler ones. Approximation makes it possible to reveal the general regularity, which can be expressed with a sufficient accuracy, for example, by the two-parametrical equation. According to the Nobel laureate B. Russell, "all science is subordinated to the idea of approximation".

The use of the approximating approach for carrying out examination (PEE) contributes to the effective solution of expert tasks in electrical engineering and power industry. It is reasonable to use the approximating approach for the development of analytical models.

IV. GENERAL CONCEPTS OF ANALYTICAL MODELING

A. Main Data

Before considering the essence of analytical modeling, note that the following concepts, related to the term "modelling" in the field of electrical engineering, are not considered in the article:

- Software application;
- Assessment of the input of mental labor expenses of an expert researcher developing mathematical models;
- Structural mathematical models used for constructing and the automated design of the objects located in space;
- Stochastic (probabilistic) models describing random disturbing factors & impacts on an electrical power system;
- Transition processes in the modelled scheme;
- Nonlinear, dynamic models.

Thus, we will be interested only in functional analytical models, which unambiguously describe the behavior of objects (systems) and ignore the influence of random factors.

Generally, modeling is a universal method of receiving and applying knowledge of the real world, using models for defining or specifying characteristics of existing or newly designed objects. The development of models is a characteristic of any scientific activity, aimed at the determinations of the interrelations of a studied object, causes and effects of the processes taking place in it. To simplify the analysis of the object processes and connections between the characteristics of these processes, the studied object is replaced with a simpler conditional (abstract) non-material image. This image doesn't have a real embodiment and exists only as an ideal model (in virtual reality). It is called an analytical model of the object of research which is described by means of mathematical symbols.

The purpose of the development of analytical models in our case is carrying out reliable express examination of electrical engineering calculations, using analytical models. In our case the formal technique for the mathematical description of the estimated results of electrical engineering calculations in the form of the values of the system (EPS) parameters is elementary algebra. Analytical models are presented by elementary inequalities and balance ratios in the of the algebraic equations systems. The results of the use of such models help to verify the carried out electrical engineering calculations and, respectively, to reveal and correct the factors, the influence of which can cause undesirable development. Theoretically, they are able to completely eliminate emergencies in the elements of a system (EPS).

Certainly, a model should have a certain similarity with the initial object, but it shouldn't be its complete analog. Otherwise modeling loses any sense. An analytical model is a theoretical way of perception of the world around. The essence of the analytical modeling process is that the interrelations of studied processes/phenomena are described in the form of the specific mathematical equations and inequalities. The article considers the aspects of methodology and application of the method of analytical modeling (as a kind of mathematical modeling) when carrying out on-the-spot examination and testing the accuracy of the results of electrical engineering calculations.

In analytical modeling various mathematical ratios are used for the description of functioning processes of any system elements. Analytical modeling assumes the use of an analytical method (a system of the equations of various types), by means of which exact decisions are received, obvious dependences are established, objective laws of functioning of the system and its elements are displayed. For this reason such models are also called functional analytical models.

B. Inexpediency of Models Complication

The authors consider it inexpedient to complicate models when carrying out express examination of electrical engineering calculations. The complication of models implies the transition from the first level of abstraction (with the use of algebraic ratios) to the second level (with the use of the ordinary differential equations) and to the third level of displaying real processes (with the use of the differential equations with private derivatives, the equations with the distributed parameters and equations of mathematical physics). Let us list the reasons for the inexpediency of the complication of models for carrying out the power express examination:

- Firstly, the main objective of the express examination of electrical engineering calculations is receiving the end result. Express examination doesn't involve tracing the process in time (the second level of abstraction) and, in particular, doesn't involve simultaneous tracing the process both in time and in space (the third level of abstraction);
- Secondly, transition to the second and third levels of abstraction will reduce the cost effectiveness of models and complicate them. Such complicated models can't be classified as express models.

C. Justification of the Choice of the Type of a Model

Let us substantiate the basic features of models in relation to the object of research. A linear model is a model which displays a condition of the system so that all interdependences in it are accepted as linear ones. Such model can be presented in the form of one linear equation or a system of linear equations.

When a linear model describes an organized electromechanical system by means of specific data (characteristics) in such a way that characteristics of the system don't depend on time (that is, the single segment of the information of the object without its development is given), we speak about an idealized static system. It is clear that as the static system is considered as a segment of information, it is a special condition of the dynamic system which is the main object of studying at imitating modeling. That is, the description of a static system there doesn't require the use of differential equations derivative of time (as in case of imitating modeling), specialized software and hardware complexes. It is enough to have the knowledge of algebra and an engineering calculator.

When the consequence is precisely determined by the reason, a process is described by the model deterministically. The determined model assumes lack of any casual impacts on the system and involves the use of classical mathematics methods. Analytical modeling with the use of the determined models is the preferable type of modeling due to its logical, strictly formal character, accuracy and completeness of the description.

As in the offered work the problems of the express examination of electrical engineering calculations are solved, we will qualify functional analytical models applied to examination as express models.

Besides the definition of features, the authors formulated a number of requirements to functional analytical models (algorithms, ratios). A model should:

1) To be feasible.
2) To be formalized. In other words – to translate the studied properties into the mathematical language, to calculate numerical values of the parameters characterizing these properties by means of mathematical ratios.
3) To have the general character, that is, it has to be applicable to a wide class of objects, and it shouldn't be attached only to a specific object being examined.
4) To be efficient, that is, to require the minimum amount of computing resources (first of all, time for calculation).
5) To represent the value from the point of view of its application in express examination (fast check) of any electrical engineering calculations.
6) To be precise. In other words, there has to be a high extent of coincidence of values of a real object parameters (process, phenomenon) and values of the same parameters calculated by means of an analytical model.
7) To allow both analytical (by means of an algebraic method), and numerical (calculation) verification of the model correctness.
8) To be useful and easy to use.
9) To contribute to the definition or improvement of the object characteristics, a more efficient way of its construction.
10) To coordinate the input parameters with the expected results.
11) To be alternative, that is, to have the greatest number of options in stock.
12) To be based on the established terminology.
13) To be simple algebraically.
14) To allow minor errors of the calculation results.
15) To possess the property of generation of the whole class of algorithms with the set properties.
16) To have such numerical proportionality coefficients which are easily calculated and which would provide the sufficient accuracy of calculations.

Thus, on the basis of the formulated features and requirements for functional analytical models, the authors have chosen a specific type of a functional model – the linear analytical static determined express model (LASDEM). The right reasonable choice of the model type is very important, as it will determine the convenience of the implementation of the model in practice and the accuracy of the results, obtained by means of this model.

The main advantage of such type of models (LASDEM) is that these models have a compact and convenient form of the representation of results. This fact makes it possible to interpret them on a reasonable basis, and also, if necessary, to include them in procedures of further analytical transformations are calculations. In the proposed pater mainly algebraic equations are used, therefore the models (LASDEM) can also be called algebraic models.

D. A Concept of the General Theory of Express Examination of Electrical Calculations Using Analytical Models

The above-mentioned concept developed by the authors is a theoretical base for the tasks of the development of models (LASDEM) for carrying out on-the-spot examination, and it includes the following basic statements.

1) Models (LASDEM) are built for the purpose of verification of electrical engineering calculations.

2) The development of models (LASDEM) is based on the use of fundamental laws and standard notions of electromagnetism, and these models are aimed at the description of electric processes by means of algebra as one of numerous kinds of the mathematical apparatus.

3) The advantage of models (LASDEM) is that they are easy to use, as they allow making computing experiments, which are either impossible or difficult to implement in reality. Models (LASDEM) have an extremely simplified and universal form. At the same time, such extraordinary simplification of models (LASDEM) doesn't affect the reliability and quality of the final result (examination).

4) Information sources for development of models (LASDEM) are only reliable results of generally accepted provisions and applied researches in the area of electrical engineering and power industry.

5) Specific character of models (LASDEM) is that these models are simultaneously the means and the object of the research, replacing the initial object.

6) The need for models (LASDEM) and the method (PCEM), developed on the basis of these models, is related, first of all, to the fact that any expert has to carry out examination within a short time period. The examination of quality of the carried out electrical engineering calculations using the standard methods requires a long time. In other words, the expert has to repeat all those computing procedures (often carried out with the use of special expensive computer programs) which were done by the authors of the examined project. As both computer programs and the time of the expert costs a lot of money, it is necessary to develop a fast and effective method of reliable check of calculations (for example, design) which is represented in the present work by the method (PCEM) within the development of models (LASDEM).

7) Level of description of the models of this type is a mathematical one. It means that the system of equations (for our case it is the system of algebraic equations) makes it possible to create analytical models which are close to the real system (EPS).

The offered new concept in relation to the verification of the results of the carried out electrical engineering calculations contributes to the fast achievement of accurate expert results.

V. GENERAL CONCEPTS OF A PROPORTIONALITY COEFFICIENT EXPRESS METHOD

The essence of the express examination of electrical engineering calculations consists in a fast and reliable assessment of the correctness of the received results. Such assessment can be carried out using various methods. This research is devoted to the method using analytical models and an approximating approach for carrying out an individual examination. As said above, this method is called by the authors as the method PCEM. The method is aimed at the reduction of the probability of mistakes in the determination of numerical values of electrical engineering parameters for any elements of the system (EPS), and, as a result, at obtaining objective information about the electrical engineering decisions which are to be taken (or have already been taken).

The method (PCEM) is a complete system, as the elements of this method are closely interconnected with the methodology components described above – an approximating approach and analytical modeling. This system is aimed at the achievement of the purpose and solution of the tasks of express examination. In order to apply this method in practice, it should be scientifically grounded, that is, the possibility of receiving reliable results by means of this method is to be proved. The method (PCEM) is intended to be used in the case when express examination is carried out by an expert-electrician individually, without involving other experts.

It should be emphasized that it is impossible to identify the method (PCEM) with the method of expert evaluations as these approaches are absolutely different. Expert evaluation is a value judgment of experts, organized in a group with one main objective – to reduce the subjective influence of each participant of such group. Express examination is scientific research which is carried out using express methods and which gives an objective and reliable assessment on the basis of verified analytical models. Besides, it should be realized that the express method also differs from the calculation methods applied in various areas of electrical engineering. The difference is that the method (PCEM) includes analytical express models, and it can also include (if it is necessary) both special calculation methods of specific disciplines and general scientific methods of research. Summarizing the thesis about the specific features of the method (PCEM), let us emphasize that such a method is wider and deeper than special calculation methods. It is much more flexible, more accurate and more reliable than the method of expert evaluations, that is, it is much more appropriate for the expert practice.

The essence of the method (PCEM) consists in the interconnection of various parameters using proportionality coefficients, and the "construction" of various algebraic relations (equations and inequalities). Proportionality coefficients are the additional parameters in the functional equations, making it possible to accelerate the convergence of calculation results and improve their stability. The method of introduction of such additional parameters is based on elementary algebra and known electrical engineering relations, including the dependences given in special scientific and technical (electrical engineering) literature and received in an empirical way.

The coefficients of proportionality don't belong to the class of fundamental physical constants having the universal nature. We also shouldn't draw a parallel between the method (PCEM) and the method of the demand factor, which is applied in the calculation of electrical load, as well as between the method (PCEM) and the method of the coefficient of beam utilization, which is applied in lighting calculations.

The authors have developed more than 600 analytical express models for the method of the proportionality coefficient, based on an approximating approach to the on-the-spot solution of expert tasks. All these models, which were tested for reliability and are, in essence, simple analytical approximations, make it possible to carry out fast and reliable examination of calculation results for any electrical parameters in the conditions of the incompleteness of initial data.

The complete and detailed description of the proportionality coefficient method is provided by the authors in other publication.

VI. GENERAL CHARACTERISTIC OF A CONCEPTUAL FRAMEWORK, SPECIFIC FEATURES AND MAIN DIRECTIONS OF THE POWER EXPRESS EXAMINATION

A. Conceptual Framework of Power Express Examination

The power express examination is the scientific concept, which reflects the manifestation of essential properties in the system of features, and the relationships between these properties, for the purpose of carrying out prompt examination of the results of electrical engineering calculations in projects of electrical engineering and power industry. The concepts help to reveal the essence of energy facilities in their integrity. They are used to develop the system of scientific tools, making it possible to systematize the actual material in the field of electrical engineering and power industry.

Scientific concepts provide the theoretical justification of expert activity, which is the basis for a conceptual framework of the theory (GTE), in particular, the basis for power express examination as a component of the theory (GTE). When applying the methodology of examination (PEE) in various areas of electrical engineering and power industry, it must be kept in mind that in these areas there are specific concepts and specialized terminology, specific for this branch of knowledge, which is a language form of subject expression of thought in the form of terms and symbols.

The task of the present article is not to present the structure of a conceptual framework of examination (PEE), to give definition to each term, to unify the language of examination (PEE) equally relating to each subject when carrying out on-the-spot examination. This large-scale task will be set in further publications. The proposed work only presents an attempt to describe the conceptual framework of examination (PEE).

B. Specific Features of Power Express Examination

Power express examination as an estimating and analytical activity has a number of features. It is a set of methodological provisions, methods, approaches, techniques, operations and procedures of research of an examination object. Power express examination is intended to prepare the data, required for taking electrical engineering decisions in the conditions of some uncertainty, incompleteness of the available initial data. Such examination contributes to the decrease of technical risks, and the prevention of losses of resources (material, power, financial, time). On the basis of the examination results it is possible to draw a conclusion on the technical feasibility of the project. Only after drawing this conclusion it is possible to carry out examinations of other types – marketing, financial and economic, legal, etc.

At the modern level, the practical tasks of power express examination can be solved effectively only in case of taking into account the interdependence, interrelatedness of phenomena and processes occurring in the electrical power system and its elements. As power examination relates, in particular, to the area of power generation, when carrying out express examination one must keep in mind a number of the main specific features of an electrical power system which sharply distinguish it from systems in other industries. These features are as follows [8]:

1) Power generation, its distribution and transformation to other types of energy are carried out virtually in the same time point, that is, all the elements of an electrical power system (EPS) are interconnected, interact and represent an integrated whole – the energy generated in the system (EPS) is equal to the energy consumed in it.
2) Relatively high speed of the transition processes (wave processes, short circuits, switching, stability violation, etc.), taking place in the system (EPS), which last from a few millionth of a second to several seconds.
3) A system (EPS) is connected with all industries, communication, transport, etc., which sharply increases the importance of ensuring the reliability of its work.

C. Main Directions of the Development of Power Express Examination

According to the authors, the main directions of the further development of power express examination can be:

1) Adding new algorithms and ratios (equations, inequalities) to the methods of express examination with.
2) Improving the reliability of the results of express examination by the specification of proportionality coefficients in analytical models.
3) Development of methods of express examination and testing their reliability and accuracy.
4) Development of the theoretical bases of power express examination.
5) Development of new simple analytical express models for special areas of electrical engineering (relay protection and automatic equipment, electrical safety, self-start of electric motors, quality of electric power, reliability of power supply, electromagnetic compatibility, etc.).
6) Development of a conceptual framework of power express examination.

D. A Numerical Example, Substantiating the Effectiveness of the Method of Power Express Examination

To compare the performance of the calculations of electrical parameters, characterizing certain devices, systems, processes and phenomena, performed using the conventional method and the express method, let us provide a specific numerical example. This example substantiates and illustrates the effectiveness of the method of power express examination.

The power supply station is a power plant, which consists of a generator switchgear (GSG), a high-voltage switchgear (HV SG), two generators (each having a capacity of 63 MW), connected to the generator switchgear, and the generators' own needs (10% of the active power of one generator), two step-up transformers, connected to the generator switchgear, and one generator-transformer unit, having a capacity of 63 MW. Generator voltage is 10.5 kV. Active minimum and maximum loads at a generator voltage are, respectively, 50 MW and 65 MW. The active power factors of the power plant generators and of the load at a generator voltage are, respectively, 0.8 and 0.85. The transmission voltage $U_{tr} = 220\ kV$ of alternating current having a frequency of 50 Hz. The power transmission with single-end power supply is performed via a radial distribution network represented by a single (one chain) overhead power line (OHPL). The neutral point of the three-phase mains is solidly grounded (connected with the grounding device through the resistance of less than 1 ohm). The transmission distance $L = 100$ km. Each of the three phases of the OHPL is split and is implemented using three aluminum type A wires.

- *Target data.*

1. To determine the value of full power $S_{PTL.p}$, transmitted from the power plant to the power transmission line (PTL), with an allowance for the losses in the two step-up transformers of the power plant, using the conventional method and the express method of calculation.

- *Solution.*

- *1A. Conventional method of calculation*

In case of using the conventional method of calculation, only the numerical representation of the results of the calculations of parameter values is provided.

When using the conventional method of calculation of $S_{PTL.p}$, first the following 15 parameters are calculated:

- active power of own needs of one generator $P_{on} = 6.3$ MW;
- reactive power of one generator $Q_g = 47.3$ MVAR;
- minimum reactive load at a generator voltage $Q_{\min} = 31$ MVAR;
- reactive power of own needs of one generator $Q_{on} = 4.7$ MVAR;
- full power at the minimum load consumption at a generator voltage (first mode) $S_{1m} = 83.4$ MVA;
- maximum reactive load at a generator voltage $Q_{\max} = 40.3$ MVAR;
- full power at the maximum load consumption at a generator voltage (second mode) $S_{2m} = 66$ MVA;
- full power at the maximum load consumption at a generator voltage, when one generator is shut down (third mode) $S_{3m} = 8.6$ MVA;
- maximum full calculated power for one of the calculated modes $S_{m.c} = 83.4$ MVA; ;
- full power of each of two transformers, connected to the GSG $S_{t.GSG} = 58.4$ MVA;
- full calculated power of the block-type transformer $S_{bl.c} = 79.1$ MVA;
- full power of the block-type transformer $S_{t.bl} = 79.1$ MVA;
- active power, transmitted from the generators to the high-voltage switchgear of the power plant, exclusive of the losses in the step-up transformers of the power plant $P_{tr.p} = 120.1$ MW;
- full power, transmitted from the generators to the high-voltage switchgear of the power plant, exclusive of the losses in the step-up transformers of the power plant $S_{tr.p} = 150.13$ MVA;
- full power, transmitted from the generators to the high-voltage switchgear of the power plant, with the allowance for the losses in the step-up transformers of the power plant $S_{PTL.p} = 139$ MVA.

The time for the calculation of the above-mentioned 15 parameters, using a calculator, amounted to 8 minutes.

- *1B. Express method of calculation*

The express calculation formula $S_{PTL.p}$ is given without its algebraic derivation, as the derivation would take a large part of the paper.

When using the express method of calculation of $S_{PTL.p}$, no preliminary calculations are required. In this case only one calculation formula is used:

$$S_{PTL.p}(\text{MVA}) = \frac{5.787}{\frac{2500}{U_{tr}^{\,2}(\text{kV})} - \frac{1}{L(\text{km})}} = 138.93 \text{ MVA}$$

The time for the calculation of this parameter, using a calculator, amounted to 0.5 minutes.

- *Conclusion on the example*

The calculation of the resulting parameter $S_{PTL.p}$ with the use of the conventional method would require using 15 preliminary calculation formulas. To calculate the same parameter by the express method, only one calculation formula was used. The divergence of the results of the calculations of the target parameter $S_{PTL.p}$ using the conventional method and the express method amounts to 0.05%. The time for calculation of the target parameter for the example 1 by the express method was 16 times less $(\frac{8\,\text{min.}}{0.5\,\text{min.}} = 16)$ than in case of using the conventional method.

VII. MAIN RESULTS

A. The Theoretical Importance of the Research

The theoretical importance of the research consists in the following:

- The developed methodology of the express examination makes contributes to the development of the methodology of the general theory of electrical engineering examinations;
- The developed express models make it possible to reveal, analyze and describe the regularities and interrelations between various electrical engineering parameters;
- The developed express method makes it possible to receive required numerical values of any electrical parameters even in case of incomplete initial information, to predict the behavior of phenomena and processes in the elements of the electrical power system, to receive important information on fundamental properties of these phenomena and processes;
- The developed models can form a methodological basis for the search of new solutions in the field of express examination of electrical engineering calculations;
- Express models possess a property of generation of the whole class of algorithms with the set properties.

B. The Practical Importance of the Research

The practical importance of the research is determined by the fact that:

- The results of research can serve as a methodological reference point in the process of the solution of a wide range of scientific and practical applied tasks of processing and interpretation of theoretical and experimental data;
- The developed methodology makes it possible to estimate electrical parameters of any power generation facilities without using special calculation computer programs and at insignificant financial and time expenditures;
- The proposed method makes it possible to receive the result within the minimum period of time, as compared to the conventional practice, while providing a similar reliability level;
- New knowledge, materials and generalizations, obtained in the course of the research, have applied value and can be used by experts and electricians. They can also promote the professional development of personnel, form a basis for the preparation of manuals and special courses in higher education institutions of an electrical engineering profile, and can be included in training students and post graduate students.

C. The Results of the Research

The results of the research consist in the following:

- An attempt is made to formulate, substantiate and reveal the relevance of a new scientific problem – providing an easy to use and reliable express examination for energy facilities;
- The research gives an insight into the conceptual framework, specific features and the main directions of further development of power express examination;
- The research gives a general idea of an approximating approach and analytical modeling and their use for power express examination;
- The features and a number of requirements for analytical express models are formulated;
- The choice of the type of a functional analytical model of power express examination is justified;
- The reasons for the inexpediency of the complication of express models are listed.

D. The Scientific Novelty of the Proposed Research

The scientific novelty of the proposed research lies in the following:

- This research is the first to provide a holistic view of the state of the problem of energy express examination;
- The methodology of energy express examination is developed for the first time;
- Simple and reliable tools of carrying out energy express examination – an express method based on the proportionality coefficient – are developed for the first time;
- The concept of the general theory of the express examination of electrical engineering calculations, based on linear analytical static determined express models and approximating approach, is developed for the first time.

VIII. CONCLUSIONS

The set of theoretical results, obtained in the course of the research, can be qualified as the development and scientific justification of methodological tools for the prompt solution of the expert tasks of electrical engineering and power industry on the basis of an approximating approach and analytical modeling.

The theory and practice of power express examination is still at the stage of development. The proposed work on the methodology and the method of such examination is the first step in this direction. It is possible that the lack of attention to the development of power express examination is related to the fact that both in Russia and abroad the role and the importance of this type of examination is downplayed or completely ignored by administrative management methods. This results in a number of negative consequences, in particular, inefficient use of financial and human resources, slow rates of the integration of scientific and technical projects and the general decrease of the industry development rates. Scientists and experts in the field of power industry still have to accumulate, summarize, analyze and organize the experience of carrying out power express examination. Besides, the development, systematization and unification of the terminology of power express examination are required.

The development of the methodological bases of power express examination meets the necessary conditions of the advancement of science. The obtained results of the research are indicative of the development of the methodological basis of power express examination and, consequently, the solution of the set tasks and the achievement of the objective of the research.

NOMENCLATURES

EPS: electrical power system
GSG: generator switchgear
GTE: general theory of electrical engineering examinations
HV SG: high-voltage switchgear
LASDEM: linear analytical static determined express model
OHPL: overhead power line
PCEM: proportionality coefficient express method
PEE: problem of the power express examination
PTL: power transmission line

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