eoss-conf.com

ISSUE
№44

EUROPEAN OPEN
SCIENCE SPACE

COLLECTION OF SCIENTIFIC PAPERS

1[ST] INTERNATIONAL
SCIENTIFIC
AND PRACTICAL
CONFERENCE

SCIENTIFIC PROGRESS: THEORIES, APPLICATIONS AND GLOBAL IMPACT

JULY 14-16, 2025, BRAGA, PORTUGAL

EUROPEAN OPEN SCIENCE SPACE

Proceedings of the 1st International Scientific and Practical Conference

"Scientific Progress: Theories, Applications and Global Impact"

July 14-16, 2025

Braga, Portugal

Collection of Scientific Papers

Braga, 2025

UDC 01.1

Collection of Scientific Papers with the Proceedings of the 1st International Scientific and Practical Conference «Scientific Progress: Theories, Applications and Global Impact» (July 14-16, 2025. Braga, Portugal). European Open Science Space, 2025. 160 p.

ISBN 979-8-89704-969-1 (series)
DOI 10.70286/EOSS-14.07.2025

The conference is included in the Academic Research Index ReserchBib International catalog of scientific conferences.

The conference is registered in the database of scientific and technical events of UkrISTEI to be held on the territory of Ukraine (Certificate №530 dated 16.06.2025).

The materials of the collection are presented in the author's edition and printed in the original language. The authors of the published materials bear full responsibility for the authenticity of the given facts, proper names, geographical names, quotations, economic and statistical data, industry terminology, and other information.

ISBN 979-8-89704-969-1 (series)

EUROPEAN OPEN SCIENCE SPACE

CONTENT

Section: Mechanics and Electrical Engineering

PROSPECTS AND FEATURES OF THE APPLICATION OF INTEGRAL EQUATIONS IN ELECTRICAL ENGINEERING PROBLEMS

Sytnyk Oleksandr
Dr. Sc., Professor
Klyuchka Kostyantyn
PhD., Associate Professor
Protasov Serhii
PhD., Associate Professor
Department of electrical engineering's systems
Cherkasy state technological university, Ukraine

Due to progress in the fields of electrical engineering and power engineering, there is a constant complication of problems related to the analysis and design of electrical devices. This necessitates the improvement of modern methods of mathematical modeling, numerical analysis and computer calculation of electrical circuits. Problems related to the study of dynamic processes in such circuits remain particularly difficult from an analytical point of view.

A typical example, common in practical applications, is electrical circuits with a complex structure, which contain elements with both lumped and distributed parameters. Such structures are an integral part of many modern electrical and electronic systems, which imposes increased requirements on their models, in particular, the need to use non-traditional approaches to modeling that can take into account the heterogeneity and complexity of such circuits.

In addition, in cases where the initial information for calculation or design is presented in the form of experimentally obtained dynamic characteristics (for example, transient or impulse functions), traditional parametric models built on the basis of differential equations in some cases turn out to be insufficiently effective. Under such conditions, the most appropriate is the use of non-parametric models that are formed directly on the basis of dynamic characteristics. Such models include, in particular, mathematical structures in the form of integral operators or integral equations.

The classical approach to the construction of algorithms and software for the analysis of transient processes in electrical circuits is based on the numerical implementation of systems of differential equations. This approach is the basis of most modern universal and specialized serial application software packages that provide the ability to perform the corresponding calculations.

Despite the high degree of development and widespread implementation of numerical methods implemented in the specified software, they have a number of qualitative limitations. In particular, difficulties arise when solving problems related to complex electrical circuits of large dimensions, systems with impulse disturbances, as well as circuits with a variable structure. These features significantly complicate the application of traditional algorithms in specific engineering problems and require the development of alternative methodological approaches.

One of the promising directions for overcoming these difficulties is the use of computational algorithms built on the basis of non-traditional dynamic models presented in the form of integral or integro-differential dependencies. Such models are analytically equivalent to classical systems of differential equations, but are implemented by fundamentally different numerical methods that take into account the specific features of nonparametric descriptions. The numerical methods used within this approach have a pronounced specificity and are able to provide high efficiency in solving problems with atypical characteristics - in particular, in cases of variable topology, impulse effects or high dimensionality of electrical circuits. It is worth noting that although the areas of application of traditional and alternative methods may partially overlap, they differ significantly in the principles of model construction and approaches to numerical implementation.

In addition to traditional problems related to the analysis of dynamic processes in systems known by their structure, considerable attention is paid to the class of problems in which the study of dynamics is carried out without prior knowledge of the laws of the functioning of objects. These include, in particular, inverse problems of analysis – identification, synthesis of control systems, diagnostics of the state of electrical and electronic circuits, etc.

A significant contribution to the development of the methodology for the analysis of dynamic systems was made by the formalized interpretation of their properties through the concept of aftereffects, as well as the further development of the structural approach to research. This contributed to the introduction of integral operators as an effective mathematical tool for describing the elements and structures of systems in general. As a result, integral equations have been widely used in solving a wide range of problems related to the modeling of dynamic objects and systems of various natures.

Integral calculation methods are characterized by a number of important advantages, including the compactness and convenience of the mathematical formalism for describing electrical circuits, high versatility of models, and increased stability of the numerical implementation of integral relations [1]. One of the key properties of such methods is the ability to smooth errors in experimental data, which is especially important when using empirical information [2].

Within the framework of the integral approach, the relationship between input influences and output reactions of the system is given by integral operators. In this case, their kernels play a dual role: on the one hand, they fully determine the internal characteristics of the corresponding mathematical model, and on the other hand, they are interpreted as the reactions of the system to typical input signals, which gives them direct physical and engineering significance [3].

One of the promising directions of such expansion is the development of specialized methods and algorithms for numerical analysis of transient processes in electrical circuits, built on the basis of dynamic models in the form of integral equations. The implementation of these approaches can significantly increase the accuracy and flexibility of modeling complex electrical systems, especially in conditions of limited a priori information about their parameters and structure.

In the general case, the behavior of an arbitrary electrical circuit can be formalized in the form of a system of integral equations of the Volterra-Urison type

$$y_i(t)+\sum_{j=1}^{n}\int_{t_0}^{t} H_{if}\left[t,s,y_j(s)\right]ds=\sum_{q=1}^{m}\int_{t_0}^{t} G_{iq}\left[t,s,f_q(s)\right]ds, \quad (1)$$

$y_i(t)(i=\overline{1},\overline{n})$ unknown quantities (currents, voltages); $f_q(t)(q=\overline{1},\overline{m})$ – functions depending on external sources and initial conditions; H_{ij} i G_{iq}, – transforming characteristics of elements.

For linear electric circuits, the corresponding dynamic properties are described using the system of Volterra linear integral equations, which is a simplification of the general nonlinear formulation given in expression (1).

$$y_i(t)+\sum_{f=1}^{n}\int_{t_0}^{t} H_{ij}(t,s)y_j(s)ds=\sum_{q=1}^{m}\int_{t_0}^{t} G_{iq}(t,s)f_q(s)ds, \quad (2)$$

the kernels $H_{ij}(t,s)$ i $G_{iq}(t,s)$ have the meaning of weight functions.

Analysis of existing applied software indicates an obvious lack of tools capable of providing effective modeling of a wide range of electrical circuits, the dynamics of which are described by integral and integro-differential equations. This situation emphasizes the relevance and scientific and practical significance of the task of expanding the functionality of existing open software packages.

References

1. Verlan A. F. Integral equations: methods, algorithms, programs. / A. F. Verlan, S. S. Sizikov – K.: Naukova Dumka, 1986. − 543 p.
2. Verlan A. F. Method of integral equations in the problem of identification of parameters of electrical circuits / A. F. Verlan, K. N. Klyuchka // Bulletin of Cherkasy State Technological University, 2011. − No. 1. − P. 55-58.
3. Verlan A. F. Method of identification of electrical circuits based on integral dynamic models. / A. F. Verlan, O. O. Sytnik, K. M. Klyuchka // Proceedings of the third international scientific and technical conference “Modeling in electrical engineering, electronics and lighting engineering MEES’2010”, Kyiv. 2010. − P. 24-26.