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MODELING OF A SAFE ELECTRICAL SUPPLY MODE FOR PRODUCTION PREMISES

Energy efficiency and energy saving, energy security, monitoring, diagnostics and management of energy processes and equipment are currently particularly relevant issues in the energy industry. The energy system of Ukraine has a number of problems that require both urgent and systemic solutions. This applies not so much to capacities and generation, but to the "arteries" of the system, which include high-voltage transmission lines, power distribution systems, transformers, substations, and those devices that ensure the transportation of electrical energy from generation to the consumer. To ensure the European level of customer service, the energy industry needs systematic modernization of distribution networks. One of the components of a complex solution to the above-mentioned problem is the development of methods for finding all possible modes in networks of arbitrary configuration when calculating stable modes of electrical networks.

A number of works are dedicated to the theory of creating geometric models of multidimensional space, to the development of methods and means of their research, which confirm its effectiveness in the automated modeling of modern production processes. Computer graphic modeling allows you to ensure the completeness and visibility of the research being conducted, expands the possibilities of forecasting, analysis and process management. Existing methods of calculation allow finding one or, in the best case, several separate solutions. The use of the proposed method of geometric modeling of stable modes of direct current electric networks with n consumers in the form of corresponding multispecies as models of complex multiparameter dependencies allows to create algorithms for calculating such modes. It also allows automated modeling of multi-parameter processes of various physical nature in energy. Geometric means of solving the applied problem of calculating steady-state modes of electrical networks illustrate the wide possibilities of geometric modeling of the studied dependence in the form of a manifold, which guarantees the completeness of the solution and its clarity.

Key words: geometric modeling, manifold, multiparameter dependence, steady state of the power grid.

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МОДЕЛЮВАННЯ БЕЗПЕЧНОГО РЕЖИМУ ЕЛЕКТРОПОСТАЧАННЯ ВИРОБНИЧИХ ПРИМІЩЕНЬ

Енергетична ефективність та енергозбереження, енергетична безпека, моніторинг, діагностика та управління енергетичними процесами та обладнанням на сьогодні є особливо актуальними питаннями в енергетичній галузі. Енергетична система України має низку проблем, які потребують як невідкладного, так і системного вирішення. Це стосується не стільки потужностей, генерацій, скільки «артерій» системи, до яких відносяться лінії високовольтних передач, системи розподілу потужностей, трансформатори, підстанції, ті пристрої, які забезпечують саме транспортування електричної енергії від генерації до споживача. Для забезпечення європейського рівня обслуговування споживачів енергетичне господарство потребує системної модернізації розподільних мереж. Одним із складників комплексного вирішення вищезазначеної проблеми є розроблення методів знаходження всіх можливих режимів у мережах довільної конфігурації при розрахунках усталених режимів електричних мереж.

Теорії створення геометричних моделей багатовимірного простору, розробленню методів та засобів їх дослідження присвячено ряд робіт, що підтверджують її ефективність при автоматизованому моделюванні процесів сучасного виробництва. Комп'ютерне графічне моделювання дозволяє забезпечити повноту і наочність досліджень, що проводяться, розширює можливості прогнозування, аналізу та управління процесами. Існуючі способи розрахунку дозволяють знаходити один чи, в кращому випадку, декілька окремих розв'язків. Використання пропонованого методу геометричного моделювання усталених режимів електричних мереж постійного струму з n споживачами у вигляді відповідних багатовидів як моделей складних багатопараметричних залежностей дозволяє створити алгоритми розрахунків таких режимів. Це також дозволяє здійснювати автоматизоване моделювання багатопараметричних процесів різної фізичної природи в енергетиці. Геометричні засоби вирішення прикладної задачі розрахунку усталених режимів електричних мереж ілюструють широкі можливості геометричного моделювання досліджуваної залежності у вигляді багатовиду, який гарантує повноту рішення і його наочність.

Ключові слова: геометричне моделювання, багатовид, багатопараметрична залежність, усталений режим електричної мережі.

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Problem statement

Currently, the energy system of Ukraine is in a state of "great stress". In addition to problems that require an urgent solution, there are also those that require a systematic solution. This applies not so much to capacities and generation, but to the "arteries" of the system, which include high-voltage transmission lines, power distribution systems, transformers, substations, and those devices that ensure the transportation of electrical energy from generation to the consumer (Fig. 1). Energy efficiency and energy saving, energy security, monitoring, diagnostics and management of energy processes and equipment are currently particularly relevant issues in the energy industry.

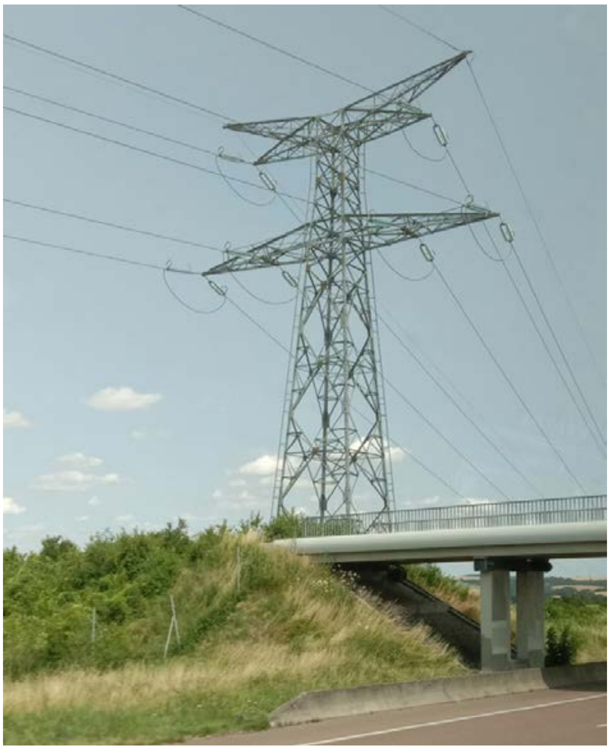

Fig. 1. “Arteries” of the energy system

The general requirements for the criterion of the quality of functioning of a complex system, which also include distribution electrical networks, are specified in [1]. Today, a sufficient level of quality and reliability of electric energy transmission is not ensured. At the same time, the functioning of modern production with its complex technological complexes, with the wide application of systems of automatic control and control over processes is not possible without the clear operation of all technical means. To ensure the European level of customer service, the energy industry needs systematic modernization of distribution networks.

Analysis of the latest research

Scientific-analytical and scientific-research articles by Ukrainian and foreign specialists based on the results of the studies, directly aimed at solving fundamental problems and solving applied problems of the development and functioning of distribution networks of Ukraine and other countries of the world [2], testify to the need for wider research into this segment of the national energy industry.

A number of works are dedicated to the theory of creating geometric models of multidimensional space, to the development of methods and means of their research, which confirm its effectiveness in the automated modeling of modern production processes. Computer graphic modeling allows you to ensure the completeness and visibility of the research being conducted, expands the possibilities

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of forecasting, analysis and process management. The creation and research of geometric models of multidimensional space is highlighted in a number of theoretical works [3, 4], as well as works of a practical direction [5], containing methods and means of automated modeling of processes, particularly in energetics [6].

One of the components of a complex solution to the above-mentioned problem is the development of methods for finding all possible modes in networks of arbitrary configuration when calculating stable modes of electrical networks. The use of rational manifolds as models of complex multiparameter dependencies in computer graphic modeling ensures completeness and clarity of research and actual automation of calculation processes of all possible modes in electrical networks of arbitrary configuration of the studied system.

Objective of the research

In order to increase the reliability of electricity supply to consumers, it is advisable to involve various means of solving the specified problem, including geometric means involving the possibilities of modern information technologies. Existing methods of calculation allow finding one or, in the best case, several separate solutions. The proposed solution to the given problem illustrates the broad possibilities of geometric modeling of the investigated process in the form of a manifold, which guarantees the completeness of the solution and its visibility, allows to track the operation of the system and establish intersystem connections.

Main part

To develop an algorithm for calculating all possible modes in power grids of arbitrary configuration using rational manifolds to identify the reasons for existence and finding all ambiguous modes, let us consider the solution of the applied problem of calculating steady-state modes of electrical networks using multiple species as models of the studied multi-parameter dependencies.

The steady state of direct current electrical networks with *n* users (points) is described by a system of algebraic equations of the second order with respect to the unknowns u_s and p_s:

$$\sum_{s=0}^{n} \cdot \sum_{i=0}^{n} u_s j_i = p_s, \tag{1}$$

where u_s and j_i – respectively, voltage and current vectors at the points,
p_s – the power of points.

$$J_i = Y_{is} U_s, \quad i, s = 0,1,\ldots,n,$$

$$Y_{is} = \begin{Vmatrix} Y_{00} & Y_{01} & \cdots & Y_{0n} \\ Y_{10} & Y_{11} & \cdots & Y_{1n} \\ \cdots & \cdots\cdots\cdots & & \cdots \\ Y_{no} & Y_{n1} & \cdots & Y_{nn} \end{Vmatrix} - \tag{2}$$

matrix of nodal conductances, the elements of which are given by the resistance of the sections between the *i*- and *s*- points.

Let’s rewrite system (2) in the form:

$$\begin{aligned} &Y_{i0} U_i U_0 + Y_{i1} U_1 U_1 + \ldots + Y_{ii} U_i^2 + \ldots + Y_{in} U_i U_n = P_i, \\ &i = 1, \ \ldots, \ n. \end{aligned} \tag{3}$$

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In the Euclidean space of voltages and powers $U_1 \dots U_n$, $P_1 \dots P_n$, the dimension of which is $2n$, the i – equation from (3) is considered as an analytical expression of the corresponding cylinder. The generators of the i – hypercylinder are linear $(n-1)$ – subspaces of the level parallel to the coordinate $(n-1)$ – dimensional subspace of powers $P_1 \dots P_{i-1}, P_{i-1} \dots P_n$.

In the coordinate $(n+1)$ – dimensional subspace $U_1 \dots U_n P_i$ the i – equation from (3) is considered as the guiding subspace of the i – hypercylinder.

A manifold as a geometric model, the entire set of points of which is placed in a mutually unambiguous correspondence to all possible states of the steady state of networks, is defined as the total intersection of n hypercylinders (3) in E^{2n}.

The dimensionality of the total cross-section of q shapes due to their dimensions s_i ($i = 1 \dots q$) is written as:

$$\sum_{i=1}^{q} s_i - m\,(q-1), \tag{4}$$

where m – the dimension of the space in which the intersection is sought.

That is, for the considered example of the mutual intersection of n hypercylinders of the 2nd order, the E^{2n} general intersection will be a manifold Π_n^{2n}, that is, a manifold of dimension n and order $2n$ according to (3). Each point of the n-manifold Π_n^{2n} corresponds only to its corresponding combination of number-coordinates $U_1 \dots U_n$, $P_1 \dots P_n$ that defines one of the possible modes of operation of the network, and the entire set of its points – all possible modes of operation of the electrical network under study.

Thus, by setting specific power values from the entire set of network operation modes, only those that correspond to the specific case of the specific power values of the points in question are selected.

The geometric solution of this problem is reduced to the construction of the mutual intersection of n-manifolds Π_n^{2n} (3) by the system of n hyperplanes of calculated level. According to (4), we obtain a submanifold in the intersection Π_o^{2n}. The set of found points (real or imaginary) determines all possible modes of operation of the network (real or imaginary) for a particular case of values P_i P^i_1. In particular, if all the $P_i = 0$ sought points are at the mutual intersection of asymptotic directions in the voltage subspace $U_1 \dots U_n$.

The sought-after manifold, the entire set of points of which is placed in a mutually unambiguous correspondence to all possible states of the power system, as a geometric model of possible regimes in power networks, is studied by submanifolds constructed in this way. At the same time, each point of the manifold Π_n^{2n} corresponds only to its corresponding combination that determines one of the possible modes of operation of the network, and the entire set of its points – all possible modes of operation of the electrical network under study, thanks to which the reasons for existence are revealed and all ambiguous modes of the power network are found.

When calculating stable modes of electrical networks, the question of finding all possible modes in networks of arbitrary configuration is relevant. Existing methods of calculation allow finding one or, in the best case, several separate solutions. The proposed solution to the given problem illustrates the broad possibilities of geometric modeling of the investigated process in the form of a manifold, which guarantees the completeness of the solution and its visibility, allows to track the operation of the system and establish intersystem connections.

Conclusions

The use of the proposed method of geometric modeling of stable modes of direct current electric networks with n consumers in the form of corresponding multispecies as models of complex

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multiparameter dependencies allows to create algorithms for calculating such modes. It also allows automated modeling of multi-parameter processes of various physical nature in energy.

The proposed algorithm for calculating all possible modes in power grids of arbitrary configuration using the method of multidimensional geometric modeling makes it possible to identify the reasons for the existence of ambiguous modes, gives an answer to the question of the number of solutions and, as a final result, leads to the finding of all ambiguous modes. Solving these problems makes it possible to create a complex of improved programs for calculating steady-state modes of electrical networks, which allow simulating real processes in electrical networks, which is very relevant in connection with the further development of energy systems of Ukraine.

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