Research of Methods of Optimal Design of Special Electric Drives

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Abstract. Problems of optimization of special electrical and electromechanical systems in modeling, creation and design are solved mainly by methods of mathematical programming. The task of mathematical programming is to find extremes of the function of many variables in the presence of restrictions on variables, which creates fundamental difficulties. To solve such problems, the number of methods for solving the general problem of mathematical programming is currently expanding significantly. In this regard, the trend in the development of mathematical programming is following the path of highlighting and studying various subclasses of problems. The use of certain specific features of the tasks of the selected subclass creates opportunities for their more effective investigation and solution. Examples of such subclasses give convex, quadratic, linear programming problems, transport-type problems, and others. Geometric programming is also a section of mathematical programming that research a certain class of optimization problems. However, when using geometric programming, you have to apply linear, nonlinear programming, the concept of convex programming. Using optimization methods will allow you to correctly investigate, design and create special electric drives.

1. Introduction

The tasks of creating new electrical [1-2] and electromechanical systems [3-4] and structures [5-6] are given a satisfactory amount of time and resources. To do this, methods of mathematical modeling [7-8], optimization [9-10], computational complexes [11-12] with new algorithms for finding optimal solutions [13-14] are used. To create special electric drives [15-16] for various industries [17-18], it is necessary to solve the problems of determining parameters and dynamics of change of such systems [19-20]. These are such parameters as: magnetic induction [21-22], electromagnetic flux [23-24], electromagnetic field strength, force [25-26], electromagnetic moment on the shaft [27-28] and power [29-30] of special electric drives. This will improve performance and stabilize parameters for new efficient systems of special electric drives.

Let's consider methods of optimal design of special electric drives using the example of geometric programming. The problem of geometric programming is to minimize some positional, for example, a positive polynomial under constraints. According to the restrictions, the values of some other positioners should not exceed ones. The theory of duality is also used. The dual problem is built on the original line and is the problem of maximizing a nonlinear function under linear constraints on variables. As a rule, solving the dual problem is much easier. According to the theory of duality of geometric programming, the minimum value of a direct function is equal to the maximum value of a
dual function. At the same time, if the optimal solution of the dual problem is known, the problem of determining the optimal values of the variables of the direct problem is reduced to solving systems of linear equations.

Geometric programming is a very convenient tool for solving a number of optimization problems in the field of special electrical and electromechanical systems. Especially important is the fact that the study of the dual problem makes it possible to obtain some qualitative dependencies of the optimal value of the objective function on various parameters of the problem. This circumstance is used to solve a large class of applications.

2. Basic provisions of geometric programming
Solving technical problems requires an optimal approach for using various alternative ways of solving problems, for example, when optimizing some certain characteristic, or searching for a design with maximum efficiency, minimum costs or with minimum weight.

Technical design characteristics depend on both fixed and adjustable parameters. Fixed parameters, such as cost of materials, energy, project specification, are constant for the task in question, but change from one task to another. Adjustable parameters such as dimensions, pressure, speed, voltage and current can be set.

With the traditional approach to optimizing special electric drives, parametric curves are built for constant values of fixed parameters. The best design is chosen by cross-comparison. Until recently, another approach was popular when the researcher relied entirely on a digital computer that was looking for an optimal project for constant values of fixed parameters. With none of these approaches, it is impossible to achieve a deep understanding of the relative technical significance of all project parameters. An attempt to correct the situation led to the creation of geometric programming.

The main requirement of this method is that all technical characteristics of special electric drives be expressed quantitatively in the form of generalized positive polynomials from adjustable parameters. This requirement allows efficient use of the geometric mean and a large number of geometric concepts such as vectors, vector spaces, subspaces, orthogonality and normalization.

Geometric programming has a number of advantages over conventional methods. Firstly, this approach reveals a fairly complete picture of the comparative significance of various parameters of special electric drives. Second, geometric programming, especially when limited, is more suitable than conventional techniques for digital computers. Thirdly, this method is more closely related to the engineering essence of the task of optimizing special electric drives. In particular, the required method of replacing the restrictions written in the form of equalities with restrictions-inequalities forces from the very beginning to analyze the interaction of various parameters of special electric drives. These advantages of geometric programming can be illustrated by numerous tasks from various fields of technology.

Mathematical disciplines usually arise when there is a need to solve new problems dictated by reality. Geometric programming, following this traditional scheme, has developed in connection with the tasks of engineering design and optimization. When designing a device or system, there are usually both fixed and adjustable parameters. The researcher seeks to set adjustable parameters so as to obtain an optimal design. The optimal project can be defined in various ways. A typical optimal design is one in which the device or system operates in a certain way at minimal cost. The attempt to develop a rapid systematic method of compiling such optimal projects was essentially an incentive for the development of geometric programming.

The basis of the geometric programming method is the systematic use of the properties of inequalities. Since Fermat, many authors have noted that some inequalities help solve special optimization problems. However, they did not give a general theory, like developed in geometric programming.

The mathematical wording of the problem of optimizing special electric drives is called a program. Geometric programming is one such formulation. It is designed so that it is general enough to consider a wide class of engineering tasks and at the same time specific enough to provide useful quantitative
information for optimizing special electric drives. This formulation is expressed in terms of functions that we call positive polynomials or, for brevity, positionomas.

The problem of minimizing the position \( g \) subordinate to the constraints of a certain form is called a direct program. Let \( M \) be the minimum value of the direct function \( g \) in the presence of restrictions. It turns out that there is a corresponding problem of maximizing the function \( v \), which is called a dual function. The problem of maximizing a dual function \( v \) subordinate to certain linear constraints is called a dual program. It is found that \( M \), being a conditional minimum \( g \), is also a conditional maximum of the function \( v \).

The purpose of this research is to show the origins and basic ideas of geometric programming using the example of optimal design of special electric drives. In particular, some properties of the dual program will be revealed.

3. Maximum dual function

The problem is to prove that there are positive weights \( \delta_i \); satisfying the orthogonality conditions, and that the maximum of the dual function \( v \) is equal to the minimum of the direct function \( g \). It is assumed that the minimization problem is formulated correctly. By this we mean that the position \( g \) has a minimum value at some point \((t_1', t_2', \ldots, t_m')\), all the coordinates of which are positive. At the minimizing point \( t_i' \), the derivatives \( g(t) \) for each variable go to zero, and we get a certain number of equations of the type

\[
0 = t_j' \frac{\partial g(\vec{t})}{\partial t_j} = \sum_{i=1}^{n} t_j' \frac{\partial u_i(\vec{t})}{\partial t_j} = \sum_{i=1}^{n} u_i(\vec{t})a_{ij} \quad (1)
\]

where \( g \) – poziny;
\( t_j \) – project settings;
\( t_j' \) – parameter minimization point;
\( a_{ij} \) – arbitrary real numbers;
\( u_i \) – components of the positioner \( g \).

Dividing these equations by \( g(\vec{t}) \) and defining

\[
\delta_j' = \frac{u_i(\vec{t})}{g(\vec{t})}, \quad (2)
\]

where \( i = 1, 2, \ldots, n \).

find that

\[
0 = \sum_{i=1}^{n} \delta_j'a_{ij}, \quad (3)
\]

where \( j = 1, 2, \ldots, m \)

Thus, the vector \( \delta' \) satisfies the orthogonality conditions. Further, it is clear from (2) that \( \delta' \) satisfies the normalization condition. Then

\[
g(\vec{t}) = (g')^{\delta_1} \cdots (g')^{\delta_n} \quad (4)
\]

but, according to (2)
(g')^k \ldots (g')^{l_k} = \left( \frac{\delta u_{k}(t)}{\delta v_{k}} \right)^{l_k} \ldots \left( \frac{\delta u_{l_k}(t)}{\delta v_{k}} \right)^{l_k} \quad (5)

Then it follows from (3) that

\[ g(t') = v(\delta t') \quad (6) \]

Equation (6) shows that the conditional maximum of the dual function \( v \) is equal to the minimum of the direct function \( g \). The variables shown in equations (1) to (6) may be electrical and structural parameters of special electric drives.

4. Conclusion
The results of the use of the geometric programming method will make it possible to realize the task of optimally designing special electric drives. This method is a special case of nonlinear programming. The solution, using optimization methods, will allow conducting research of optimal geometry, weight and size parameters, electrical and electric power characteristics of special electric drives for various industries.

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