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DECISION MAKING FOR RATIONAL MODES REGULATION OF HETEROGENEOUS ELECTRIC NETWORKS

The article investigates the possibility of using genetic algorithms to solve optimization problems of heterogeneous electric networks. The mathematical model of decision-making regarding rational modes regulation of power systems with a high degree of networks heterogeneity is suggested.

Key words: *electric power system, heterogeneity, decision making, optimization, intelligent search, genetic algorithm.*

Introduction

Modern electric power systems combine electric network of various classes of nominal voltage, consisting of over-head transmission lines or cable lines, realized of various types of wires with different mutual location of phase wires in space, etc. The above-mentioned factors define heterogeneity of electric networks of electric power systems. Formally, heterogeneity of electric networks is defined as the inequality of impedance angles of electric network sections. It is known, that heterogeneity of electric networks is connected with additional stray flows of power in electric systems, that cause additional losses of power and worsen technical economic indices of electric power system operation. Besides, stray power flows in closed loops of heterogeneous electric networks unload transmission lines of the highest class of nominal voltage and overload transmission lines of the lower voltage that leads to inefficient usage of electric networks of superhigh nominal voltage and decrease of carrying capacity of the network [1 - 4].

Nowadays, a wide spectrum of measures, aimed at partial or complete compensation of electric network heterogemeity is known, namely, change of geometric characteristics of the overhead transmission lines, usage of additional sources of reactive power, application of the devices of series compensation of transmission lines parameters, usage of addition sources of reactive power, application of phase shifters and linear regulators, change of transformation ratios of power transformers and autotransformers and other modern technologies of flexible electric transmission lines [1, 5, 6]. Saturation of electric networks with various means of heterogeneity compensation determines the task of their rational usage. Here, the optimization problem of minimization of certain function of compensation devices parameters that defines the least possible resources consumption for expedient compensation of electric network heterogeneity. Conventional methods of such problems solution are based on minimization of technical economic indices of electric systems operation, in particular – total losses of active power, equivalent fuel consumption at electric power plants, discounted integrated expenses for construction and operation of electric network, etc [1, 6, 7]

It should be noted that application of conventional methods of multifactor functions optimization is limited by a number of factors. In particular, the common practice of technical economic substation of the basis of economic indices is based on objectivized indirect indices of energy systems operation and does not provide all-round evaluation of the alternative variants of possible solutions [8]. Also it is expedient to take into account the discrete character of efficiency function, that requires the application of additional methods in the process of optimization problem solution.

Material and results of the research

The problem of decision-making, regarding the selection of optimal composition and parameters of the devices for compensation of electric network inhomogeneity in general case may be presented as the problem of optimal (acceptable) solution search in multifactoral space of states. The usage of the models of intelligent search [9] is limited by a number of factors. Methods of noninformation

(blind) search guarantee the determination of optimal solution of the problem only after the total exhaustive search and comparison of all possible design solutions. However, as a result of high dimensionality of multifactoral space of the search, application of such methods is often connected with the problem of combinatorial explosion and it can not be realized in real conditions. Another group of heuristic methods is based on artificial limitation of search space and further comparison of economic efficiency of limited volume of alternative solutions. '' Weak link'' in the process of usage of heuristic methods of search is human factor, when the lack of practical experience of the person who makes a decision, results in the fact that the most efficient and perspective decision may be rejected by him at the prior stage of artificial limitation of search space.

Genetic algorithms, suggested by the author for the solution of mode optimization problems in of inhomogeneous electric networks in multifactor search space [10 - 13], substantially are deprived of the above – mentioned drawbacks. Classic genetic algorithm, suggested by J. Golandotti simulates the adaptation of the population to the preset fitness function.

Genotype fitness refers to average number of descendants, generated during the life of a person of such genotype in certain conditions of the environment. In general case, operation process of classical genetic algorithm is a consecutive change of populations (generations), that consist of a fixed number of persons. The greater is fitness function value, the greater is the fitness of the corresponding genotype (this principle is easily adapted regarding minimization tasks). In the process of formation of the next generation part of descendants is completely identical to parental persons and part of them changes in a certain random manner under the impact of mutation and crossing over operators. It is obvious that classical genetic algorithm can be adapted to the solution of optimization problems, in particular, problems of optimal parameters composition of the devices for compensation of heterogeneity of electric networks search.

Main idea of the suggested approach is to present characteristics and properties of possible solutions by means of binary code and formation of the vector that contains binary chains of solution variant properties.

Evidently, that such vector to some extent corresponds to simplified mathematical model of the genotype of biological organism, that contains the complete information about this organism. The given case enables to apply basic genetic operations of crossing over that will lead to the formation of new solutions with new properties.

Evaluating function, stipulated by the parameters of heterogeneity compensation devices is formed, this function corresponds to evaluation of biological organism fitness to the conditions of the environment. Formation of possible solutions is realized iteratively, on the base of presiding generations, using genetic operations of crossing over, inversion and mutation, applied randomly according to stochastic laws. Solutions, characterized by the highest values of evaluating function of efficiency, that guarantees gradual improvement of the quality of the suggested solutions, have the priority during the crossing over.

Usage of genetic searching algorithms provides the consideration of various, often non typical solutions of the suggested problems [11-14], that is the main advantage of the approach, suggested by the author. We will also mention certain additional positive qualities of genetic search method [12]:

1) Simplicity and transparency of realization;
2) Possibility of paralleling;
3) Simplicity of coding and decoding of information;
4) Reduced probability of search process looping in local optima.

At the same time, using of genetic algorithms or optimal solution search is connected with the following drawbacks of the methods, to be taken into consideration in the process of practical problems solution:

1. High iteration of the algorithms;

2. Considerable dependence of the genetic search efficiency on its parameters;
3. High probability of premature convergence of cyclic search.

Mathematical models of the method

Solution of decision making problems regarding the determination of the composition and parameters of the devices of electric networks heterogeneity compensation using the tooling of genetic algorithms lies in consecutive realization of the following basic procedures [11 – 14]:

1. Determination of the composition of limitations, that define pragmatic aspects of electric energy system operation and formation of the totality of features, characteristic and properties that enable to personify the differences between generated project solutions.

2. Determination of genetic information coding method, that defines the characteristics of specific possible solution. Here, each attribute of the devices for heterogeneity compensation is coded by the bit binary chain (vector) – chromosome:

$$h = \frac{x - \min}{(\max - \min)(2^n - 1)},$$

where x – is numerical value of the parameter of the device for heterogeneity compensation in the format with the floating point; min, max – minimal and maximal value of the parameter, correspondingly; n - length of the chromosome, i. e., number of bits of binary vector for storing of the coded attributive parameter.

$$h = \frac{x - \min}{(\max - \min)(2^n - 1)},$$

Unification of all the chromosomes, that determine the properties of project solution, forms the genome, that contains all genetic information on the whole. For the formation of binary chains Grey code is used, it provides single Hemming distance between contiguous values of project solutions parameters that guarantees the lack of " deadlook" generation in search process[11]

3. Formation of evaluating fitness function, that determines the expediency and efficiency of generating project solutions

$$f(x_1, x_2, \ldots, x_m),$$

where x1, x_2, …, x_m – variation parameters that determine specific solution.

The function of reduced discount expenditures that defines efficiency of the suggested solution, function of total expenditures of power or equivalent fuel expenditures at electric power plants may be used as evaluating function. As it was mentioned above, economic criteria of design solutions accepted in design practice are objective and do not reflect to a considerable extent the expediency of the suggested solution. Here, in author's opinion, other efficiency criteria of the suggested solutions may be used, for instance, those, that model verbal evaluations of generated solution quality and are constructed using fuzzy logic tools [9, 13].

4. Determination of the composition of initial population of possible solutions and filling, by means of random number generator, their genotypes.

5. Calculation of fitness function values of the suggested solutions efficiency of the current generation and mean value of the fitness function of the total population on the whole. Problems, regarding the attaining the convergence of genetic algorithm are also considered here. Further

procedures are executed in case of convergence lack.

6. Selection of genetic material is aimed at the choice of the suggested solutions, characterized by the highest values of fitness function. As a result of performing operation of selection parents pairs of the suggested solutions are formed. Solutions, characterized by the highest values of fitness function have the priority.

7. Realization of cross-over operation, that is the crossing of information chains of genetic material of all parent pairs and formation of daughter project solutions, that inherit the characteristics of both "parents". In this case the type of cross-over and point of genomes description is determined randomly and daughter's genotype is formed.

8. Realization of mutation operation, that is the random change of genotype of daughter's elements, determined at the previous stage of algorithm execution. Type of mutation (simple mutation or inversion) is determined randomly. In case of simple mutation gene, that changes its binary value on the opposite one is determined randomly. Inversion is random determination of two points of rupture and "turning over" the part of the genome of daughter between these points.

9. Random determination of population element, that will replace the formed daughter's genotype in the next generation. Here the priority for replacement have the solutions, that are characterized by the least values of fitness-function.

Further the control is transferred to procedure 5 for performing the next step of genetic algorithm and formation of the new generation of possible solutions.

It should be noted that the considered algorithm is not the only possible, its various modifications are often used, for instance, at the stage of performing selection, the composition of parents pairs may be defined by means of rejection the most inefficient solutions or applying the method of tournaments organization.

Important problem, connected with using genetic algorithms in the problems of optimization of inhomogeneous modes of electric networks is algorithm adjustment. Such characteristics of the algorithm as number of elements of initial population; duration of life cycle of elements; method of parents pairs formation at each stage of algorithm operation; determination of possible adjustments of crossing over operations and mutations are to be selected. The problem of genetic algorithm arrangement is a multifunctional problem and does not have single-valued typical solution. For instance, decreased value of population volume is characterized by insufficient variety of genotypes and may lead to untimely convergence of the algorithm to local optimum, that does not correspond to the desired solution of optimization problem. On the contrary, excessively overestimated number of population elements often leads to inefficient crossing over of unpromising solutions that complicate and considerably decelerate the coincidence of the algorithm. Similar situation is observed with the arrangement of mutations characteristics. Main purpose of mutations is to provide sufficient diversity of genotypes, that enables to withdraw the search process from local optima of multifactoral space. That is why insufficient intensity of mutations does not provide needed diversity of genotypes. On the contrary, excessive enthusiasm regarding mutations in the process of performing genetic algorithm may worsen qualitative characteristics of generated project solutions and considerably slow down the process of evolution.

In author's opinion, for the adjustment of search algorithms of efficient solution of the problem of the compensation of electric network inhomogeneity fuzzy logic tooling, that provides "fine" adjustment of the algorithm in multidimensional regulation space would be useful [9, 13].

It should be noted, that the suggested algorithm of heterogeneous electric networks optimization can be applied both at the stage of electric power system design, particularly, for the selection of the composition and determination of the location of heterogeneity compensation device [15], and at the stage of determination of current parameters of such devices in the process of electric systems operation.

Conclusions

1. Electric networks of modern electric power systems are characterized by high level of inhomogeneity, that provides application of special measures, aimed at heterogeneity compensation, reduction of power losses and increase of carrying capacity of the electric network. Wide range of possible measures of heterogeneity compensation defines the setting of the problem of determination of optimal composition and parameters of such devices at the stage of electric system design and its operation. Efficiency function of such problem has discrete character, that requires the application of special procedures and modification of optimization methods.

2. Mathematical model and algorithm of decision making regarding the determination of the composition and parameters of the devices, intended for compensation of heterogeneity in electric networks, based on apparatus of genetic algorithm is developed. The suggested approach provides the consideration of various, especially, non-standard solutions of optimization problems, that guarantees the revealing of the most efficient solution in multifacroral search space.

3. Application of genetic algorithm of heterogeneous electric networks mode optimization is characterized by high efficiency and better properties as compared with the methods of non-information and heuristic search, that provides the revealing of optimal solution in the whole space of the search at acceptable number of steps.

4. Efficient usage of mathematical apparatus of genetic algorithms in the problems of decision-making aimed at deformation of the composition and parameters of the devices intended for compensation of electric networks heterogeneity requires the solution of the problem of algorithm parameters adjusting – volume of initial population, duration of the life cycle of generated solutions, method of parents pairs formation, probabilistic characteristics of genetic operations, etc. For the solution of such problem the author assumes to use fuzzy logic tooling, that provides realization of the “fine” adjustment of genetic algorithm, based on verbal evaluations of its operation.

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