GENETIC ALGORITHM OF DEFINITION OF OPTIMAL ELECTRIC POWER SYSTEM CONFIGURATION

ГЕНЕТИЧЕСКИЙ АЛГОРИТМ ОПРЕДЕЛЕНИЯ ОПТИМАЛЬНОЙ КОНФИГУРАЦИИ ЭЛЕКТРИЧЕСКОЙ СИСТЕМЫ

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Abstract: *This paper presents, general formulation and new solution to actual scientific and applied task of developing new methods of the high voltage distribution networks reconfiguration based on mathematical devices of genetic algorithms, that provide additional reduction of electricity losses and its quality improvements, when increasing 6 (10) kV networks to 20 kV voltage class. New method of the electrical power distribution network reconfiguration at normal mode was developed using of genetic algorithms, which on the basis of electrical power network modes enables determination of an optimal scheme configuration so that losses of power transportation were minimal provided that standard quality of electric power with voltage at consumers’ connection points assured and minimum connectedness of electrical power network scheme and minimal economic losses from power underproduction maintained.*
KEYWORDS: *HIGH VOLTAGE DISTRIBUTION NETWORK, RECONFIGURATION, GENETIC ALGORITHM*

1. Introduction

Problem of topology change often occurs while using distributive electrical power networks. By topology change is meant the working circuit design reconfiguration for the purpose of expenses minimization for electrical power networks maintenance under condition of appropriate power quality supply. Indeed, each of possible working circuit design is characterized by a gang of such parameters as reliability of an electric power supply, quality of electrical energy in points of subscribers’ affixion, power losses on a transmission of electrical energy. It determines an urgency of optimization problem statement of working circuit design configuration of distributive electrical power network.

2. Background and means for solutions Problems

It is worth to admit that nowadays for the solution of identification problem of an optimal configuration of the distributive electrical power networks, scientists usually use the estimated models, based on comparison of several alternatives of electrical power networks configuration. In most cases system diagrammes reconfiguration is carried out by one criterion while imposing restrictions. Classical optimizing models and methods have not been widely spread because of an exploring problem complexity that is caused by following factors [1, 2, 3, 4, 6, 7, 8]:
- the problem of electrical power networks configuration optimization is multicriterion, its solution should consider requirements of profitability, electrical supply reliability, electrical energy quality, preservation of the environment etc. in the conditions of reliable formalizable network states absence;
- optimization methods of distributive electrical power network configuration should consider dynamical character of electrical supply system development;
- optimality function of electrical power network configuration is discrete and contains ruptures;
- the information about of electrical system parameters has probability and even uncertain character.

The purpose of investigation is work out an optimal reconfiguration method of the working circuit design of the distributive electrical power network on the basis of genetic algorithm.

3. The solution of the problem

The shape of criterion function is offered for the solution of identification problem of optimal working circuit design reconfiguration of the distributive electrical power network. It allows simultaneously by four measures (minimum coherence of the circuit design, to diversion of voltage, an economic component of outage losses, active power losses) to provide formation of optimum system configuration:

$$F = k_1 \sum_{i=1}^{N} K_i + k_2 \sum_{i=1}^{M} |\delta U_i| + k_3 \sum_{i=1}^{M} \alpha_i P_i Y_i + k_4 \sum_{i=1}^{L} \Delta P_i \rightarrow \mathbf{min} \quad (1)$$

where k_1, k_2, k_3, k_4 - the weight coefficients intended for joint as a part of criterion function of incommensurable parameters; K_i - alarm coefficient, equal to unity in a case if contacts i switch apparatus are closed, and to null if contacts i switch apparatus are open; N - total of the switch apparatus which spot a configuration of the working circuit design of the electrical network; δU_i - diversion of running voltage i point of the circuit design a permissible limit; M - total of branch points as a part of the circuit design; α_i - extent of restriction of a loading i point of the working circuit design in case of origination of emergency perturbation; P_i - an active power of a loading i point of the circuit design; Y_i - the specific economic deficits caused by restriction of a loading i point of the circuit design; ΔP_i - active power losses on i section of the working circuit design of the distributive electrical network; L - total quantity of sections as a part of the working circuit design.

It is obvious that in expression (1) first component of function optimality provides the underload connectivity of the working circuit design of a branch circuit; second component - electrical energy quality in points of affixion of subscribers on voltage; third component - reliability of an electrical supply, that is an economic component of an outage losses; fourth - profitability of operation system mode with power losses in a network.

At definition of numerical meanings of weight coefficients it is recommended to reduce all four components of criterion function to one order, for example to one, and to consider their mutual influence thus it is possible to accept following correlation at an installed power network P_s:

$$\begin{cases} k_1 = 1/N; \\ k_2 = 1/M; \\ k_3 = \frac{1}{P_s Y} = \frac{1}{(3{,}5\ldots4)P_s}; \\ k_4 = \frac{1}{P_s}. \end{cases} \quad (2)$$

The offered optimality function of the working circuit design configuration of the distributive electrical power network is the composite nonlinear discrete function of many variables, which shape restricts the use of traditional methods of optimization, in particular, methods of nonlinear programming, for example, Lagrangian multiplier method, gradient descent. That’s why, for identification of optimal working circuit design configuration of the distributive electrical power network the genetic algorithm has been used proceeding from the offered criterion function.

The basic idea of the offered approach is to represent the characteristics and properties of possible solutions of branch circuit configuration by means of a bit pattern and vector formation, containing binary chains of alternatives circuit solutions properties. It is obvious that such vector of certain extent matches to the simplified mathematical model of a genotype of the biological organism, containing the full information about this organism. Specified condition gives the chance to apply the basic genetic operations of crossing,that will lead to formation of new solutions with new properties.

Therefore, it is possible to present working circuit design configuration of the explored electrical network by means of the bit chain, each bit of which contains the information on a state of a matching section of the circuit design («0» - if the section is the open connector and is not a part of loadings cover section of the associated subscribers; «1» - if the section is in-process). The overall space of search consists of 2^n possible states, where n - total of circuit design sections of the electrical power network.

Since the electrical power network may contain hundreds and thousands sections, problem solutions of optimal network configuration becomes very complicated. For the purpose of work acceleration and efficiency raise of genetic algorithms and probability decrease of incoherent circuit design consideration of the electrical power network, it is offered to restrict artificialy space of search by zone allocation unconditional attractor power supplies, which contain the sections of the circuit design, that provide a power supply of certain users at any combinations of admissible parameters regimes (voltage on tyres of power supplies, powers of loading etc.). Other part of the circuit design formes "boundary" zone, in which the search of disposing places of reserve connectors for the purpose of optimum sectioning of a distributive circuit is directly carried out. Allocation of unconditional attractor zones of power supplies and "a boundary" zone within the circuit design of the distributive electrical power network allows to reduce essentially search space of the optimal solution and to raise application efficiency of mathematical apparatus of genetic algorithms to the solution of an optimising problem without necessity of additional labour-consuming control of connectivity of the working system diagramme conditions.

Thus in the electrical power network the boundary zone with the restricted quantity of sections on which the breaker can be switched on or switched out is defined. Boundary zone sections form a bit chain for genetic algorithm. Graphical interpretation of border zone is presented on fig. 1.

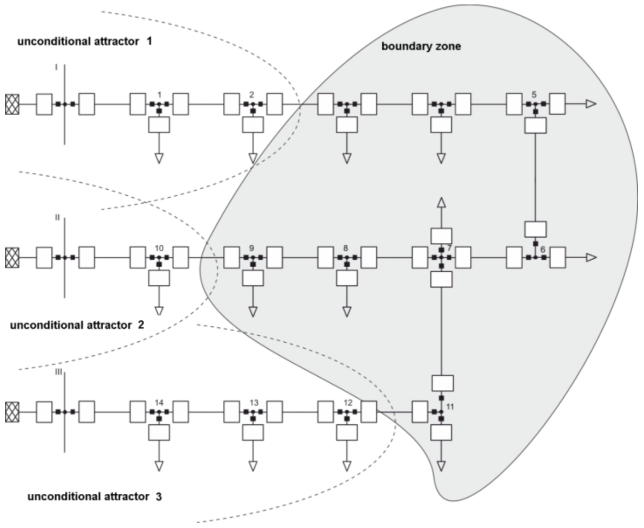

Fig.1. *Graphical interpretation of a boundary zone of the electrical power network*

The developed method [9] of optimal distributive electrical power network reconfiguration using the apparatus of genetic algorithms consists in of following procedure executions:

1. Looking through in succession and in pairs all power supplies of a branch circuit and on the basis of the minimax approach figuring out unconditional attractor zones of each source. For this purpose loading powers of subscriber's substantions of one power supply are maximized and loading powers of other power supply are minimized. Further defining a circuit design section, which the electric centre of loadings belongs to proceeding from expression

$$l_x = \frac{\sum_{i=1}^{N} P_i l_{0i}}{\sum_{i=1}^{N} P_i} \qquad (3)$$

where N - total of sections of a line with a duplicate service; l_i - length *of i th* section of the circuit design; P_i - an active-power of loading of point in the end of *i th* section; l_{0i} - distance from the line beginning up to the end *i th* section.

Conditional exclusion of this section divides the circuit design on two inconsistent parts, one of which defines a zone unconditional attractor of the current power supply. Such operations carry out also for other power supplies. The part of the circuit design, which has not got to composition of any unconditional attractor, forms a boundary zone (fig. 1), in which search of places of disposing of reserve connectors will be carried out.

2. Defining a way of coding of the genetic information about distributive electrical power network configuration. For this purpose the bit chain is formed, which length is equal to quantity of sections as a part of a boundary zone. Each bit of such chain defines a condition of a matching section of the circuit design («1» - the section is in-process, «0» - the section is a reserve connector).

3. Forming initial population of possible configuration solutions (circuit designs) of the distributive electrical network. The volume of initial population depends on dimensions of a quantity of a boundary zone of the circuit design and lies within 20-30 individuals. Forming a phenotype of all configurations of circuit designs, that is individuals of initial population. One of such individuals should match the initial circuit design of a branch circuit. Other phenotypes fill by means of the random-number generator with a uniform distribution.

4. For all individuals of initial population of possible working circuit design configurations counting meaning of criterion function (1), which defines the degree of the matching configuration solution optimality. Also defining average meaning of criterion function for initial population as a whole.

5. Forming a wheel of "roulette" for definition of current parental pair of circuit design configurations of the distributive electrical power network. For this purpose a conditional wheel is divided into sectors. Quantity of sectors equals to quantity of individuals of current population. The width of sector should be that more than less meaning of criterion function for the matching configuration solution. Width of each sector in relative unit define on expressions

$$F_i' = \frac{1}{F_i}\ ; \quad \Delta_i = \frac{F_i'}{\sum_{i=1}^{N} F_i'} \qquad (4)$$

where Fi - meaning of criterion function for the circuit design of current population; i - an index of the current circuit design (individual) as a part of population; N - total of circuit designs as a part of population; Δ_i - width of sector of "roulette" which answers *i* to th circuit design of population in relative unit.

6. By means of the random-number generator with a uniform distribution, "starting" a wheel of "roulette" twice and defining two individuals of the current population, genetic material of which will be used for the formation of a new daughter design.

7. To chosen parental pair applying the genetic operator of two-point crossover, and forming of the new daughter solution as a result of this execution.

8. By means of the random-number generator with a uniform distribution defining application necessity of the genetic mutation operator to the generated new phenotype and in case of need applying such operator.

9. For the new configuration solution on expression (1) computing a value optimality criterion functions.

10. Forming a wheel of "roulette" for definition of current population individual, which will replace the generated new solution. In this case width of sectors of a wheel should be that more than more meaning of criterion function of a matching phenotype. Such width in relative unit compute on expression

(5) $$\Delta_i = \frac{F_i}{\sum_{i=1}^{N} F_i}$$

As a result width of each sector of "roulette" is directly proportional to meaning of criterion function for the matching configuration solution. By means of the random-number generator with a uniform distribution carrying out one-shot "start" of a wheel of "roulette" and defining the individual of current population who will replace the new daughter configuration solution. Carrying out such replacement and compute average meaning of criterion function for the updated population of circuit designs.

11. Verifying conditions of convergence of genetic algorithm. If the quantity of generations of the generated daughter solutions has attained limiting meaning or all phenotypes of current population of possible configurations of circuit designs of the electrical network have coincided to one solution, work of genetic algorithm finish, and the best configuration of the circuit design of current population (with the minimum meaning of criterion function) accept as the optimum solution. Otherwise carry out the following cycle of genetic algorithm, since procedure 5.

4. *Results and discussion*

The developed method of defining of optimal circuit designs reconfiguration of the distributive electrical power network with use of genetic algorithm has been tested on a subsystem of the electrical power network, which has formed by feeders 4 and 18 the electric power substation "Gnivan", feeder 20 the electric power substation "Gnivan" and feeder 22 the electric power substation «CFD» (fig. 2).

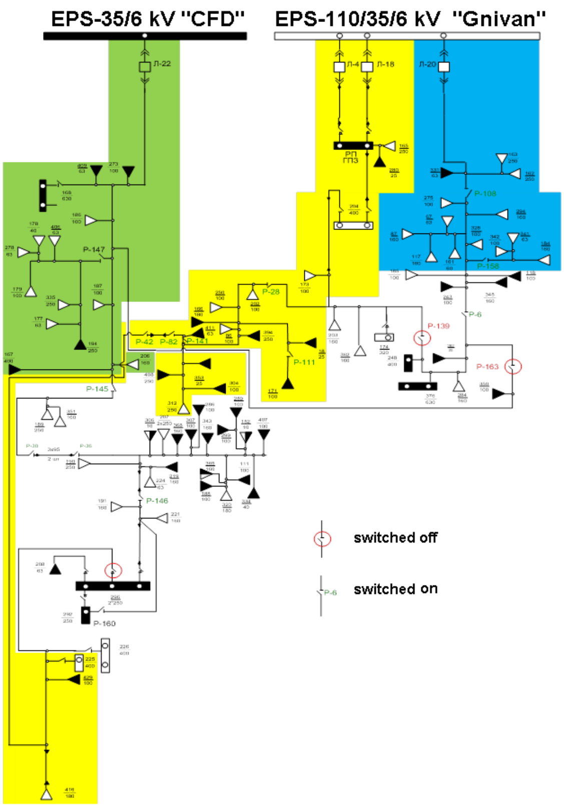

Fig. 2. *The branch circuit with figured out unconditional attractor feeders and a boundary zone*

Not figured out part of the circuit design with 52 sections represents a boundary zone. The condition of connectors of an observed zone in genetic algorithm is represented as a binary chain of 52 bit. For example, “FFFEFFDFFFF7F”.

Initial population of a boundary zone of genetic algorithm consists of 20 circuit designs, one of which is a configuration of the working circuit design at a current rule of reserve connectors, genotypes of all others are filled by means of the random-number generator. Execution of genetic algorithm is illustrated on the diagramme fig. 3. Here curve $F_{\min}(g)$ represents a time history of meaning of criterion estimated function optimality in generations for the best design; $F_{\mathrm{mid}}(g)$ - a time history of average meaning of estimated function for all generation as a whole.

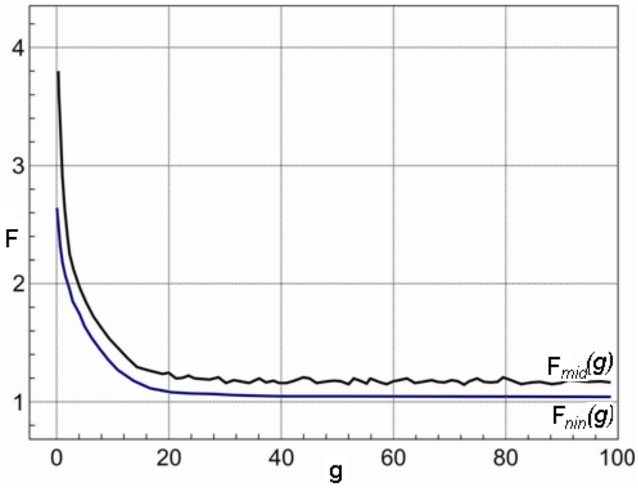

Fig. 3. *Meanings of criterion function in generations*

From fig. 3 it is visible that after execution of 30 full cycles of genetic algorithm, meaning of criterion function for the best individual practically does not change that demonstrates achievement of process of search convergence. The optimal boundary zone of the circuit design of the investigated electrical network is presented on the circuit design fig. 4.

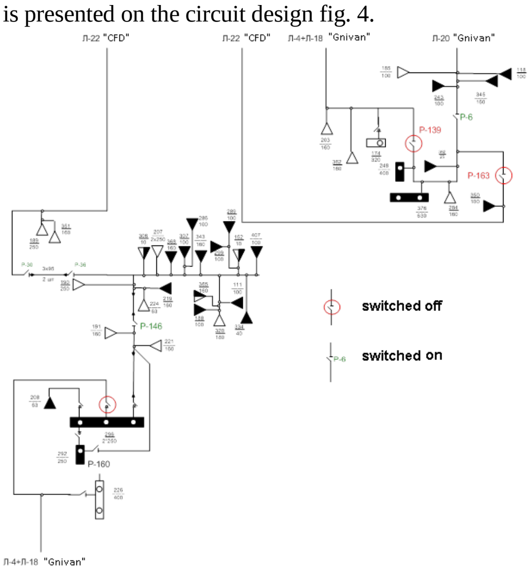

Fig. 4. *An optimal boundary zone of the electrical power network circuit design of the in the thirtieth generation*

5. *Conclusion*

Practical application of genetic algorithm for optimisation of distributive electrical power networks configuration has confirmed efficiency of the offered method of optimal reconfiguration of the distributive electrical power network. The above example of this method shows that optimal reconfiguration of branch circuit has given the chance to decrease active-power net losses approximately on 10 % (with 0,19 MW to 0,17 MW) at maintenance of appropriate quality and reliability of an electrical supply. During algorithm implementation it is observed about 600 alternatives of configurations on a boundary zone, that represents less than 0,01 % of the general space of search at execution the full circuit design reconfiguration of a branch circuit.

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