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Influence of the iteration step size to finding solutions

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Abstract. The article considers the issues of obtaining a network configuration by the criterion of maximizing the reliability index. The rationally designed configuration of the gas distribution network for the selected gas supply scheme ensures reliable operation throughout the life of gas pipeline. The results are recommended in designing of gas distribution networks, as well as when determining the reserve for improving the reliability of the network for the adopted gas supply scheme for subscribers.

1 Introduction

Russia is a unique country in terms of its size and climatic indexes. The policy of maintaining and developing the fuel and energy complex is aimed to taking into account differences in the natural and climatic and socio-economic conditions, the specifics of the regions [1]. It is necessary to achieve environmental efficiency in the use of natural gas, ensure the country's energy security, the regulatory reliability of the production structure of energy and the satisfaction of current domestic demand.

The design of reliable gas distribution networks and the optimization of existing networks does not lose its relevance. However, there is no widely used methodology for determining and improving the reliability of the network at the current time in the Russian Federation.

2 Literature review

Reliability of gas distribution systems – is the ability of the network to deliver the required amount of gas to consumers in compliance with the required parameters during operation for a specified period of time [2,3].

Taking into account the fact, that network damage has a probabilistic nature, as well as the fact, that accidents on various network elements can cause various damage to the system, the reliability of the gas distribution network must be determined in accordance with the recommendations, proposed by the methodology [4] using formula (1):

$$R_s(t) = 1 - \left(1 - \frac{1}{e^{\sum \omega_i \cdot t}}\right) \frac{\sum_{i=1}^{n} \left(\omega_i \Delta Q_j\right)}{\sum \omega \cdot Q_0} \quad (1)$$

where ω_i – the failure flow parameter for the network element, 1/year;

t - the estimated period of time for determining the reliability index of the system, year;

ΔQj - gas volumes, which has not been received by consumers, m^3/h;

Q_0- total gas flow in the network, m^3/h..

3 Materials and methods

In the engineering problems the correct (admissible) solutions can be many, in contrast to fundamental disciplines, where the solution is always only one. However, as a rule, all solutions among the set of solutions have different technological and economic efficiency.

It is known, that the optimum point in nonlinear problems is unique and lies on the boundary of admissible solutions [5]. In view of this, it is very important to establish reliably the position of the boundary between admissible and non-admissible solutions.

The region of feasibility of the problem is determined by the admissible values of the parameters having constraints in the conditions of the given problem. The totality of such parameters forms limiting conditions in the problem under consideration. Parameters can be limited from one side (for example, only from the maximum condition - "top constraint" or minimum - "constraint from below"), but can have a certain range of admissible values (limited both "from below" and "from above") [5].

Restrictions "from below", in general form, can be written in the form:

$$f(x) \geq f(x)min, \quad (2)$$

the restrictions that follow from the maximum condition:

$$f(x) \geq f(x)max, \quad (3)$$

where x is an independent variable for calculating the numerical value of the constraint parameter.

As restrictive conditions for solving the tasks of organizing gas distribution can act:

- the minimum gas pressure at the subscriber;
- the minimum value of the reliability index;
- the maximum cost of construction of a gas distribution network.

In the problems of rational tracing of gas supply networks, the effectiveness of the solution depends on the correct choice of the algorithm for enumerating variants [5].

The search for the optimal solution is carried out by means of specific search procedures by the so-called "C" - "F" - "I" procedures [5]. "C" procedure is responsible for the speedy moving of the solution search point from the unacceptable domain of solutions to the domain of admissible solutions. Moreover, all the restrictions imposed on the solution are satisfied - there is no "generalized discrepancy" in the solution. The "F" procedure helps to move the search point inside the acceptable solutions area. From the depth of the acceptable solutions area, the search point is shifted to the boundary of admissible solutions, while the "generalized excess" is reduced and an economic effect is observed. "I" procedure repels from the border of admissible solutions in the field of unacceptable solutions or in the field of admissible solutions. This procedure is a test and is necessary in order to make sure the correctness of the received solution. Schematically saw-tooth motion of the search process is shown in Figure 3.

When solving the problem of finding the most reliable network from the possible for the adopted gas distribution scheme, there are no normatively regulated limitations. The network diameters and pressure values do not appear in the calculation method for the subscribers and the source, and, as a consequence, there are no restrictive conditions. Any solution is admissible, but only one is optimal. With this formulation of the problem, the procedure "C" is absent in the procedures "C" - "F" - "I", the application of the "I" procedure is not appropriate, only "F" is involved - the procedure resulting in the search method degeneration in the iterative gradient method [6-24].

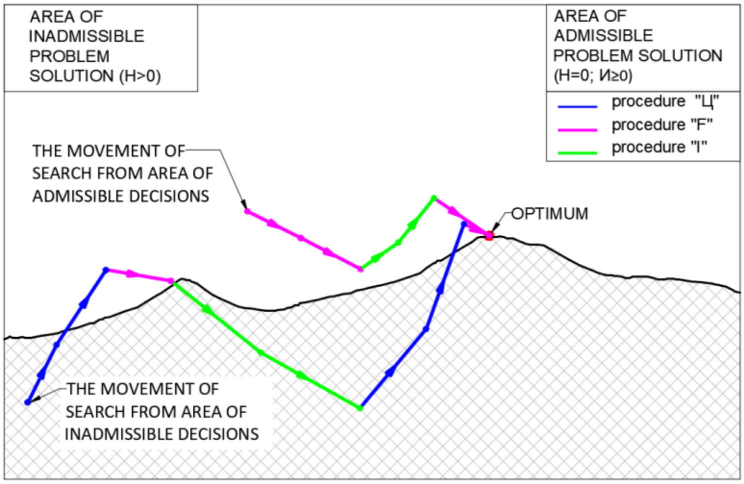

Fig. 1. The search scheme for the optimum according to the procedures "C" - "F" - "I"

4 Results of research

The movement of the search point is controlled by the construction of intermediate iterations. Intermediate are iterations, which combinations of variable parameters differ from the combination of the initial iteration by building only one parameter. The algorithm of actions for finding the optimal solution displayed in Table 1

Table 1. Iterative search algorithm schematic illustration.

No. of iteration	Variable parameter (var)	Value of objective function	Change of objective function	Comment
1	2	3	4	5
1	y_1	$f(y_1)$	-	
1.1	$y_1 + \Delta y$	$f(y_1+\Delta y)$	$\Delta f_{1.1}$	
1.2	$y_1 - \Delta y$	$f(y_1-\Delta y)$	$\Delta f_{1.2}$	the best option
2	$y_2= y_1 - \Delta y$	$f(y_2)$	-	
...	...	...	...	
3	y_3	$f(y_3)$	-	

In Table 1, Δ - is the variation of the variable parameter, f_i is the value of the objective parameter, and $\Delta f_{i.j} = f_{i.j}-f_i$.

As an illustrative example, Figure 1 presents the gas supply scheme for subscribers.

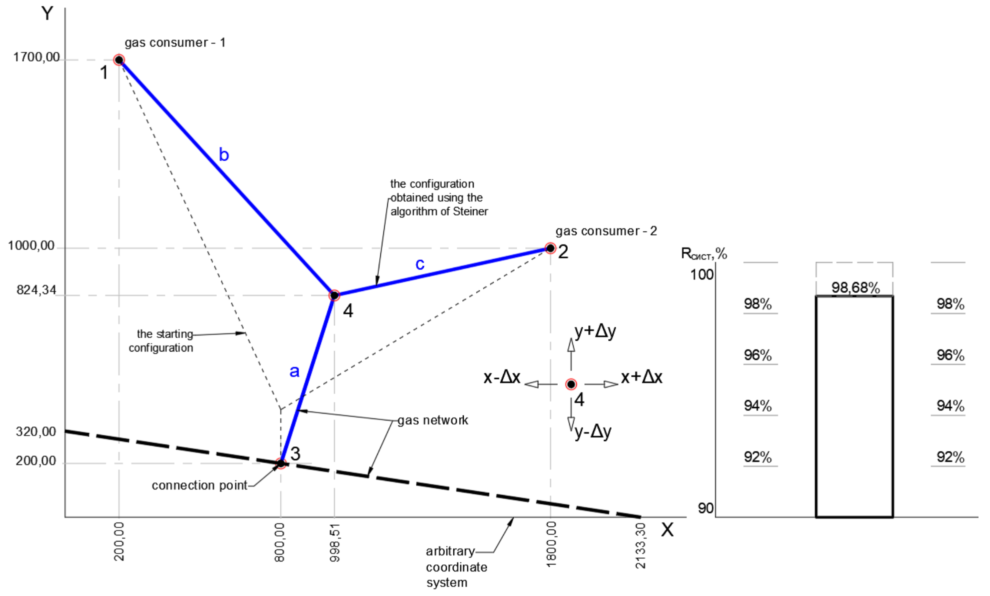

Fig. 2. The configuration of the gas distribution network considered in the task.

Subscribers located at points 1 and 2 are connected to the main gas pipeline at point 3 through an intermediate branch point 4. Considering the fact, that in this example there are no tripping devices on branches, but installed only at point 3 when connected to the main line, the reliability of the gas distribution network depends only to the length of the network. Using the Steiner algorithm, we define the net of the minimal total length and display it in Figure 1. For the given network configuration, with the gas distribution scheme adopted, we determine the reliability index of the gas distribution network using formula (1) of this paper.

Using the mathematical apparatus of the search technique, changing the geometric characteristics of the network for the accepted gas distribution scheme, we define the configuration of the gas distribution network from the starting location of point 4 with coordinates (800, 400). We will determine the network configuration by the criterion of maximum reliability with a different accepted step of the intermediate iterations. We summarize the results of the calculations in a table 2.

Table 2. Basic parameters of the iterative search.

Iteration step	number of iterations	number of calculations performed	X_4	Y_4	R_{syst}	ΔR_{syst}
1	2	3	4	5	6	7
0,5	1 246	4 984	998,5	824,5	0,986784474138300	0,0000E+00
1	622	2 488	998	824	0,986784472760860	-1,3774E-09
2,5	249	996	997,5	825	0,986784466736325	-7,4020E-09
5	125	500	1000	825	0,986784463400965	-1,0737E-08

10	62	248	1000	820	0,986784376447913	-9,7690E-08
20	31	124	1000	820	0,986784376447913	-9,7690E-08
50	31	124	1000	800	0,986781955295216	-2,5188E-06

For clarity, we will depict the graph of the dependence of the reliability index for the found optimal solution on the accepted parameter from the step size of the intermediate iterations (figure 3).

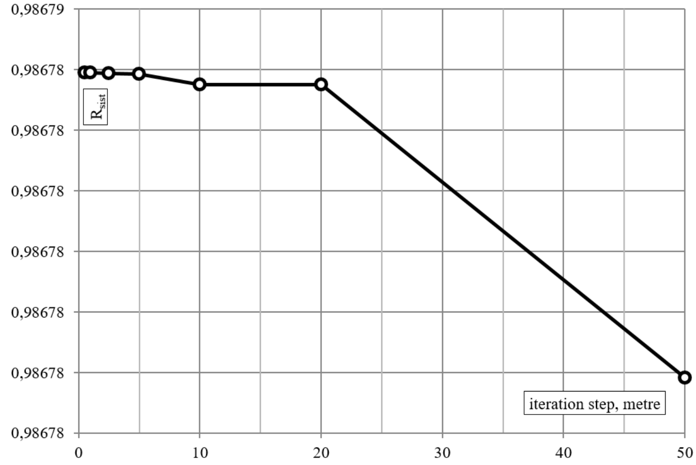

Fig. 3. Dependence of the reliability index on the step size of the intermediate iterations.

Herewith, the labour intensity of the performed calculations increases considerably with decreasing the step of the variable parameters (figure 4).

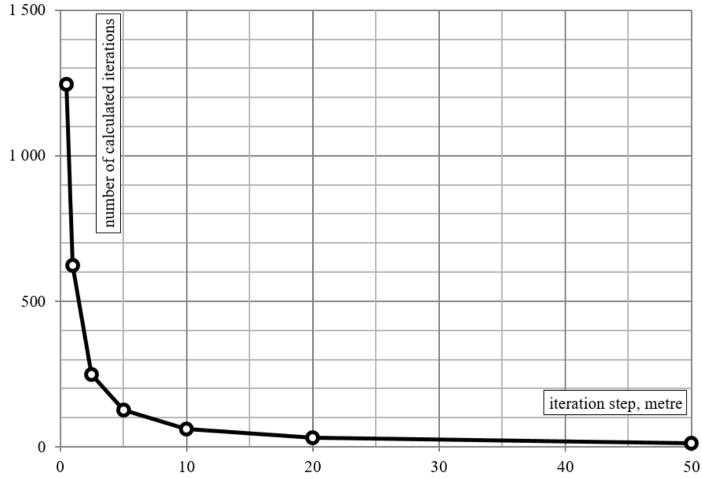

Fig. 4. Dependence of the number of iterations on the step size of the intermediate iterations.

One should not forget, however, that in order to perform the 1 iterative iteration, it is required to accomplish 4 intermediate iterations. It can be determined from the graph in Fig. 3 that it is acceptable to take a step of 5 meters or 10 meters in calculating the configuration of the gas distribution network, which corresponds to 0.25% - 0.5% of the field length in the problem under consideration.

5 Conclusions

The mathematical apparatus of the search method is able to solve the problems of determining the configuration of the gas distribution network for a given scheme of supplying subscribers using the reliability indicator of the gas distribution network as a target parameter.

If the coordinates of the variable point are taken as variable parameters when determining the configuration of the gas distribution network, the rational step is the step size equal to 0.25% - 0.5% of the larger side of the rectangle into which the master plan fits in the developed networks.

The obtained results can be used in the design of gas distribution networks of medium and high pressure, as well as in determining the margin of the maximum increase in the reliability of the network for the adopted gas supply scheme for subscribers.

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