MATEC Web of Conferences **251**, 03030 (2018) https://doi.org/10.1051/matecconf/201825103030
IPICSE-2018

Determination of high-pressure pipeline cyclization degree with exploratory technique

Aleksey Klochko* and *Viktor* Zhila

Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

Abstract. The article examines the issues of determining the network configuration, which ensures the maximum reliability of the gas distribution system. Rationally designed configuration of the gas distribution network with the adopted gas supply scheme can provide reliable operation for a long time. Results are recommended to be used in the design of gas distribution networks, as well as in determining the reserve for improving the reliability of the network for the adopted gas supply scheme for users.

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 at taking into account the differences in 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, as well as the regulatory reliability of the energy industry's production structure and the satisfaction of current domestic demand.

The design of reliable gas distribution networks and optimization of existing ones are very important. However, there is no widely used technique for determining and improving the reliability of the network at the current level in the Russian Federation.

2 Literature review

Reliability of gas distribution systems is the ability of the network to supply the required amount of gas to users and to observe the necessary parameters during operation for a specified period of time [2, 3].

The term “relative size of the distribution network ring” means the ratio of the area of the ring section of the network to the area of the maximum possible rational ring segment for a given network rf (ring factor), figure 1. The value of the indicator of the relative ring size can be determined by the dependence (1):

$$r_f = \frac{F_i}{F_{\max}}, \tag{1}$$

where F_i is an area enclosed inside a closed polygon formed by the annular part of the gas distribution network, m^2; F_{max} is an area enclosed inside a closed polygon formed by segments connecting the two nearest users of the gas distribution network, m^2.

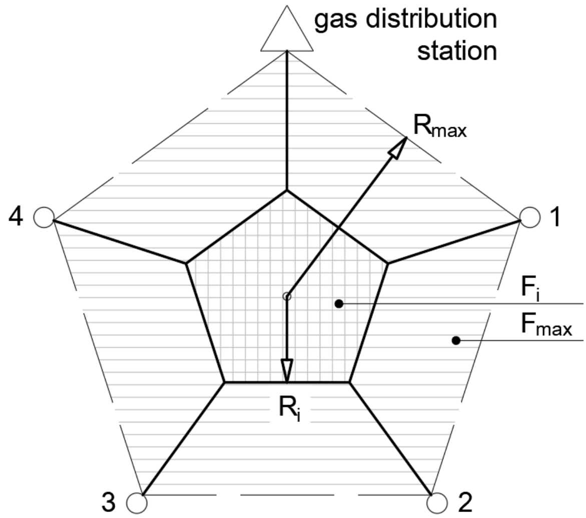

Fig. 1. Determination of the relative size of the distribution network ring

Taking into account the fact that network damages are of a probabilistic nature, and accidents in various network parts 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 (2):

$$R_s(t) = 1 - \left(1 - \frac{1}{e^{\sum \omega_i \cdot t}}\right) \frac{\sum_{i=1}^{n} \left(\omega_i \Delta Q_j\right)}{\sum \omega \cdot Q_0}, \tag{2}$$

where ω_i is the failure flow parameter for the network element, 1/year; t is the base period for determining the system reliability index, year; ΔQ_j – underlifts, m^3/h; Q_0 – total gas flow in the network, m^3/h.

3 Materials and methods

When a network has a ring (single ring) form, the radius of the ring may be different, i. e. the network can have a different relative ring size (Figure 2), and different r_f(ring factor). There are a lot of correct (permissible) solutions in the engineering problems, in contrast to fundamental disciplines, where the solution is always only one. However, as a rule, all solutions among the set of them have different effectiveness.

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

The region of feasibility is determined by the admissible values of the parameters that have limitations in the conditions of the given problem. A set of such parameters forms restrictive conditions in the problem under consideration. Parameters can be limited on the one hand (for example, only from the maximum condition – “peak limiting” or the minimum – “base limiting”), but may have a certain range of allowable value s (both “peak and base limiting”) [5].

Base limiting in the general form can be written:

$$f(x) \geq f(x)_{\min}, \tag{3}$$

Peak limiting:

$$f(x) \geq f(x)_{\max}, \tag{4}$$

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

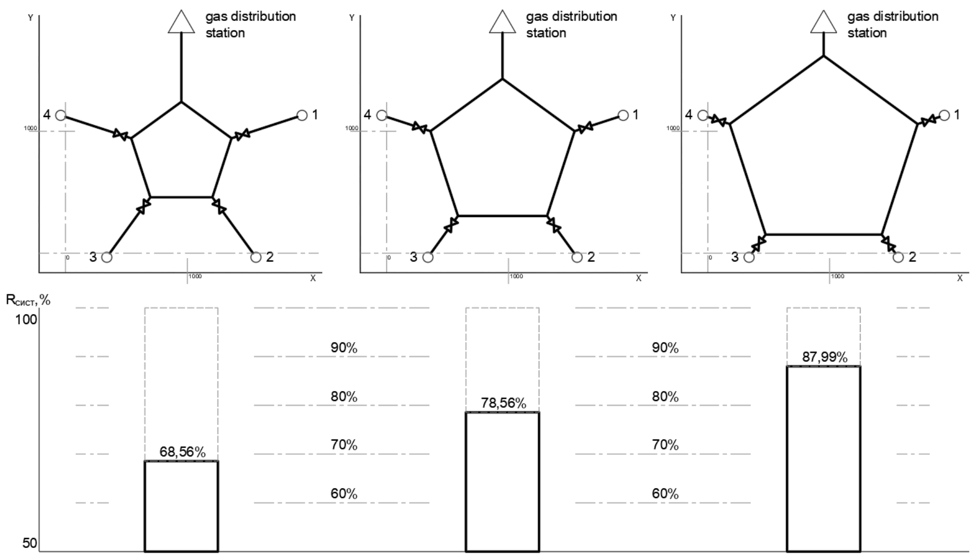

Fig. 2. The indicator of reliability of the distribution network at different relative sizes of the distribution network ring

Limiting conditions in solving the tasks of organizing the gas distribution can be minimum gas pressure; minimum value of the reliability index; maximum cost of construction of a gas distribution network.

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

Search for the optimal solution is carried out by search procedures, so-called "C"-"F"-"I" procedures [5-18]. "C" procedure is responsible for speedy movement of the solution search point from the unacceptable region of solutions to the region of feasibility. Moreover, all the constraints imposed on the solution are satisfied - there is no "generalized discrepancy" in the solution. The "F" procedure facilitates the movement of the search point within the region of feasibility. From the depth of the region of feasibility, 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 is repulsed from the boundary of admissible solutions to the region of unacceptable solutions or to the region of feasibility. This procedure is a test and is necessary in order to make sure the correctness of the solution obtained. Schematically saw-tooth motion of the search process is shown in the Figure 3.

In case of determining the most reliable network from the possible gas distribution scheme, there are no normatively regulated restrictions, the value of the network diameters and pressure values for users and the source do not appear in the calculation method, and as a consequence there are no restrictive conditions. Any solution is admissible, but only one of the admissible is optimal. In this case, the procedure "C" is absent in the procedures "C"-"F"-"I"; the application of the "I" procedure is not appropriate; only the "F" procedure remains involved. Therefore the exploratory technique degenerates into an iterative gradient method [18-24].

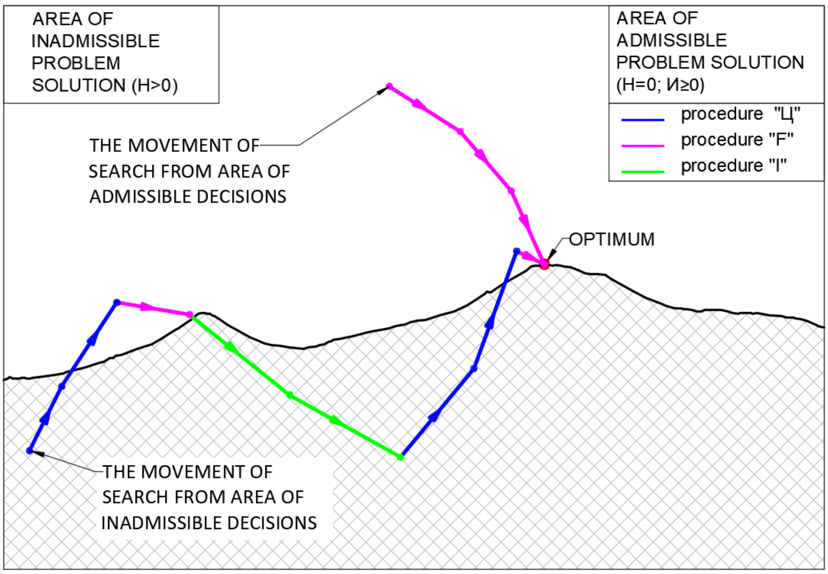

Fig. 3. Scheme of search for the optimum according to the procedures "C"-"F"-"I"

4 Results of research

The movement of the search point is controlled by the construction of intermediate iterations. Intermediate are the iterations in 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 will be displayed in Table 1.

Table 1. Schematic illustration of the iterative search algorithm

No. of iteration	Fixed parameter (fix)	Variable parameter (var)	Value of objective function	Variation of objective function	Note
1	a1	b1	f(a1;b1)	-	
1.1	a1	b1 + Δb	f(a1; b1+Δb)	Δf1.1	
1.2	a1	b1 - Δb	f(a1; b1-Δb)	Δf1.2	The best variants from the presented ones
2	a2= a1	b2= b1 - Δb	f(a2;b2)	-	
...	...	...	...	...	
3	a3	b3	f(a3;b3)	-	

In the Table 1, Δ is the variation of the running parameter; f_i is the value of the target parameter; $\Delta f_{i.j} = f_{i.j} - f_i$.

As an illustrative example, consider the gas supply scheme for users in the Figure 3.

Statement of a problem:

- a schematic diagram of the gas distribution is shown in the Figure 2;

- the estimated gas consumption of the users is the specific gas consumption by users in relation to the total gas consumption of the system. In total, we will take 4 subscribers to the settlement. The load of the network for all subscribers will be equal – 0.25 of the total network consumption;
- the calculation will be carried out at the step of the variable Δ = 5 meters.

Using the mathematical apparatus of the exploratory technique, changing the geometric characteristics of the network for the adopted gas schematic diagram, we determine the configuration of the gas distribution network with the maximum possible reliability index (Figure 4).

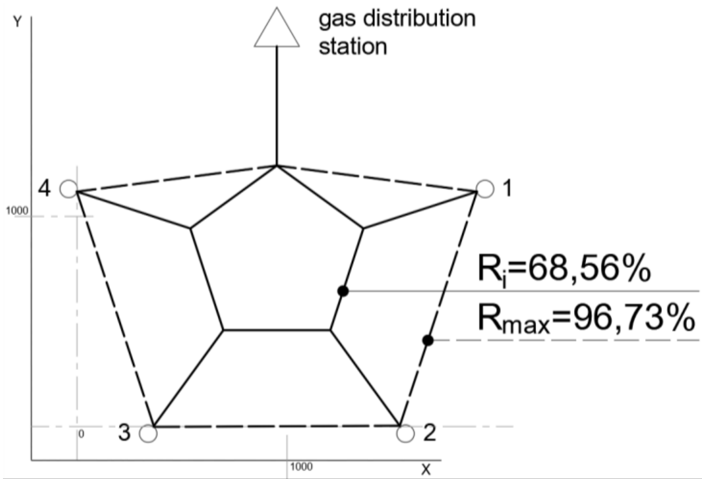

Fig. 4. Schematic diagram of the gas distribution of the settlement

It can be seen from the data in the table that the reliability of the gas distribution network at the initial search position was R_{syst} = 0.6856, and at the end of the optimization of the system R_{syst} = 0.9673. As a result, the application of the exploratory technique allowed increasing the reliability of the network by 28.17 %.

In the Figure 3, we display the configuration of the gas distribution network:
- corresponding to the initial position of the search;
- corresponding to the final position of the search.

Determine the degree of ringing of the gas distribution network, represented in the Figure 4 in accordance with the formula (2):

$$r_f = \frac{F_i}{F_{\max}} = \frac{1833471{,}0509}{2377641{,}1433} = 0{,}771.$$

5 Conclusions

The mathematical apparatus of the exploratory technique 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.

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

References

1. Russia's Energy Strategy for the Period up to 2035. URL: http://www.energystrategy.ru/ (access date: 02.09.2018).
2. A.A. Ionin *Gas supply*. Moscow (1989)
3. V.A. Zhila *Gas supply*: textbook for university students in the specialty "Heat and Gas Supply and Ventilation". Moscow (2014)
4. A.V. Laktyun'kin *Selection of the degree of ringing of the high-pressure gas distribution network for the medium-sized settlement*. (Moscow, 2018)
5. A.K. Klochko *Development of the concept of rational design of gas distribution networks by the iterative search method*: (Ph.D. thesis in Engineering Science. Moscow, 2012)
6. Gradient methods. URL: https://studfiles.net/preview/960965/(access date: 01.09.2018).
7. V.A. Zhila, A.K. Klochko, E.A. Gusarova Internet Bulletin of Volgograd State University of Architecture and Civil Engineering **3** (23), (2012)
8. R.G. Arutjunjan Housing construction **11** (2000)
9. K.A. Kuspekov. Omsk scientific bulletin **1** (107), 14-16 (2012)
10. D.A. Ejbozhenko *Approximate methods of the Steiner task solution on the oriented columns.* (Ph.D. thesis in physical and mathematical sciences St. Petersburg, 2012)
11. M.A. Bagov, V.C. Kudaev International academy of Sciences. **4**, 9-14 (2014)
12. V.N. Melkumov, S.V. Chujkin, A.M. Papshickij, K.A. Skljarov Scientific bulletin of the Voronezh state architectural and construction university. Construction and architecture. **2 (38)**, 41-48 (2015)
13. V.S. Tarasjan, D.O. Ten. Innovative transport **3** (9),29-32 (2013)
14. V.A. Litvinenko, S.A. Hovanskov, V.S. Hovanskova, E.V. Litvinenko. Informatics, computer facilities and engineering education. **4** (28), 9-16 (2016).
15. K.S. Voronin, Je.D. Shabakaeva, D.D. Shabakaev. Problems of functioning of systems of transport materials of the international scientific and practical conference of students, graduate students and young scientists (with the international participation): in 2 volumes. 18-21 (2016)
16. R. G. Arutyunyan *Determination of rational strengthening of the reinforced concrete structures, working in the conditions of seismic impacts, by search optimization method.* (Ph.D. thesis in Engineering Science. Moscow, 2000)
17. Yu. A. Tabunshchikov, D. V. Koptev, V.A. Zhila, A.K. Klochko, E. B. Soloveva Gas distribution systems efficiency preference / Scientific and technical magazine Vestnik MGSU **8**, 222 (2011).
18. K.M. Adeney, M.J. Korenberg. Neural Networks **13/7**, 787-799 (2000).
19. C.-Y. Lin, J.-J. Wang.Transactions on Signal Processing. **1**, 363-373 (2014).
20. Y. Masatlioglu, D. Nakajima. Theoretical Economics. **3**, 701-728 (2013).
21. A. Oddi, A. Cesta, N. Policella, Smith S.F. Journal of Intelligent Manufacturing **1**, 17-30 (2010).
22. U. Lechowicz, A. Pollak, A. Podgorska, P. Stawinski, M. Oldak, T. Gambin, A. Franke, B.-S. Petersen, M. Firczuk, H. Skarzynski, R. Ploski.Scientific Reports **1**, 2543 (2017)
23. R.Zhang, L. Hanzo. IEEE Vehicular Technology Conference Ottawa (2010)
24. T.H. Lin, J.J. Lin, W.J. Peng, J.H. Liu. Computers & Chemistry. **2**, 109-119 (1999)