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THE SELECTION OF RESERVED STRUCTURE AND THE CREATION OF THE FUNCTION FOR RELIABILITY

The determining of reliability of water systems is introduced, is derived formulas for definition the reliability of some water pipe structures and is made the comparative analysis of reliability and topology of these structures. The engineering method of analysis the reliability of tracing the cyclical water pipe systems is developed, which is allowed to select a structure of network with maximum reliability, is defined the limit reliability of area of network, is identified that areas which would increase the reliability of the structure during its development. The method of graph–analytic formation of tracing the new circular water pipe system was developed ed, which would given the opportunity to build a number of competitive options for trace circular water network and choose the best for reliability.

Keywords: *the reliability of the network structure, the topology, the boundary reliability of sections.*

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ВИБІР РЕЗЕРВОВАНОЇ СТРУКТУРИ ТА ПОБУДОВА ФУНКЦІЙ ЗА НАДІЙНІСТЮ

Уведено визначення надійності водопровідних мереж, отримано формули надійності для деяких структур водопровідних мереж та виконано *порівняльний аналіз надійності й топології цих структур. Розроблено інженерну методику аналізу надійності трасувань кільцевих водопровідних мереж, яка дозволяє вибрати структуру мережі максимальної надійності. Визначено граничну надійність ділянки мережі, а також ті ділянки мережі, які найбільше підвищували б надійність структури при її розвитку. Розроблено методику графоаналітичної побудови трасувань нових кільцевих водопровідних мереж, котра дала б можливість створити декілька конкурентоспроможних варіантів трасувань кільцевої водопровідної мережі та вибрати найкращий за надійністю.*

Ключові слова: *надійність структур мереж, топологія, гранична надійність ділянки.*

Introduction. Modern development of pipe line in Ukraine is moving the way of the reconstruction and intensification of existing pipe line facilities. The status of these structures is the considerable wear, low efficiency and high power consumption. A shortage of financial resources required for implementation of modern technologies and equipment and its economic exploitation, the question of resource and energy efficiency throughout the chain of water facilities, including those in the pipe line networks. But in pipe line theory up to today is not met modern research and not developed appropriate mathematical methods, which would allow to conduct efficient tracing of new and rehabilitation of existing water supply systems. Intensive development of computer technology allows you to raise these issues in a new, much higher scientific level. On the other hand, the development and introduction into practice of such methods can reduce the cost of water supply and save energy during operation and enhance reliability of networks that guarantees the consumers the water.

Analysis of recent sources of research and publications. The company Haestad Methods has developed a system WaterCAD for modeling water networks [4]. This system is based on genetic methods, which are methods of creating and structured search for the best solution in the water supply system and water distribution. The methods are using the theory of natural selection and mechanisms of genetics. It has to deal with the initial set of randomly constructed water supply and searching towards a combination which meets at least cost construction of water mains, reservoirs, pumping stations. Genetic methods creates the consistent sets of trial and the most appropriate solutions, from which then selects the best one.

The US Agency for Environmental Protection developed a program «EPANET 2.0». This program [5] provides the ability to run hydraulic model and model of water quality. «EPANET 2.0» fixes the flow of water in each pipe, the pressure in each node, the water pressure in each tank and concentration of chemicals across the network during the period simulation.

The hydraulic model is used for the following tasks: changing situations on the water supply system with the analysis of the effects of the system; assessment of crashes on consequences on water supply facilities; identify areas of low pressure; planning of the work of pumping plants the second upswing and so on.

The company «Polyterm» (St. Petersburg) supplies the software package ZuluHydro [6], which is designed to calculate water systems. The ZuluHydro performs the hydraulic calculation of water pipe network for different hydravlic work modes of pipeline water network, determined costs and the loss of pressure in all areas. For calculation the water pipeline network is defined diameters of pipes and the pressure in the connection point. The system determines the pressure in points of the water pipe network in the event of hydraulic shock. As for commutation problems, that solves of system are such as: the analysis of outage, the switching, the searching for the nearest stop valves. In addition, the system answers the following questions: how many customers remain without water, if is closed a latch; or is the pressure sufficient in the point of connection of new facilities; what kind of stop valves is used for localizing the accident.

Singling unsolved aspects of the problem. As stated in the Ukrainian Law «On Drinking Water and Water Pipe Line», one of the principles of the state policy in the field of drinking water supply is guaranteed drinking water to the population for drinking, physiological, sanitary and household needs. The implementation of this principle requires the creation of high–tech and economic systems of water supply, which is impossible without the proper research prior to the creation of such systems. Systems of submission and distribution of water, part of which is the water supply networks largely define the reliable and economic operation of all the water complex structures, and therefore require studies that meet modern requirements of customers. But the question of guaranteed economic security and water consumers can not be addressed separately from the problem of evaluating the reliability and efficiency of water supply systems, construction and improvement trace which is the first step towards the construction or reconstruction of these networks.

Setting objectives. Scientific substantiation of calculating the reliability and building the circular of water supply systems of settlements.

Basic material and results. The question the reliability and efficiency of main water supply systems are complex and aren't understood until now. The main reasons for this are:

1. The main water network cities usually has structural and functional redundancy, and therefore is difficult to identify its «failure criterion». For these networks more accurate are the property «effective functioning» when is also considered the level of failure.

2. To assessig the reliability of the basic characteristic is «denial». The fact of «failure» of main water supply network is closely linked to the consequences of failure. So is needed to assess the consequences of failure and then determine what constitutes a waiver of main water network.

3. Has not developed engineering methods of calculating the reliability of water supply network, which is the main water network cities.

4. The current rate of efficiency – the given cost – do not meet modern market conditions of functioning of municipal services of cities.

5. Generally, the term «reliability» and «efficiency» are in contradiction. For increasing the reliability is required additional investment funds, but there is no «optimum of reliability», followed by further investing virtually no increases reliability or it grows very slowly.

Everything given makes it necessary to solve the problem of optimal tracing of main water network.

The reliability and efficiency laid at the design stage as it is known. Tracking, marked on the plan of the city water network backbone is assumed as a first stage of design. The structure of the future network is called the trace [1]. That structure reflects both the topology of water network and the length of the future network, but this structure does not have the diameters of areas yet .

The first stage is the creation of water pipe network structure with the conditions of efficiency, reliability and optimization of this structure.

The second stage is hydraulical, technical and economical calculations that means the transforming the structure of optimal reliability in actual backbone network tap by calculating the optimal diameter of pipes of sections.

The study and evaluation of reliability starts with the establishment of the concept of «denial». According to [2] – is «an event that is the subject of the loss of ability to perform the desired function, therefore, working in violation of the facility». Failure criterion is formulated as a «sign or set of signs of working of the facility set in the regulatory or design documents». That should apply to the term «functional state». By definition, a «state of the object, which is characterized by its ability to perform all the necessary functions», and it's inoperable state of the object on which it is unable to perform at least one of the required functions.

During the calculating of the main hydraulic cycle in water network believes that water consumers are in knots. As a result of tracing, we get the structure of network (SN), which is the analogous of the future network (length and topology are similar), but it isn't has the diameter of sections. The most important on this stage is to determine the reliability of SN and to create the maximum reliability. When all components of SN are interconnected it names the operable condition. The maximum usable state of forms creates the covering the network of graph. In terms of probability theory of reliability of SN, R can be formulated as a probability of failure–free operation, ie the probability of the existence of at least one covering graph:

$$R = P\left(\bigcup_{i=1}^{T} B_i \right), \quad (1)$$

where B_i – is an event that is in existence of i graph;

T – the number of covering graph.

Bearing in mind that the events B_i are joint, the probability of sum of such events is:

$$R = \sum_{i=1}^{T} P(B_i) - \sum_{i \neq j} P(B_i \cap B_j) + ... + (-1)^{T-1} P(B_1 \cap B_2 \cap ... \cap B_T), \tag{2}$$

where $P(B_i)$ – is the probability of the existence of graph B_i;

$P(B_i \cap B_j)$ – the probability of simultaneous existence of graph B_i and B_j.

Formula of reliability of SN as a polynomial will look like:

$$R = a_1 r^p - a_2 r^{p-1} + a_3 r^{p-2} ... - a_n r^{p-n-1} + Tr^{p-n}, \tag{3}$$

where p – the number of sectors;

n – the number of cycles ;

T – the numbers of *SN*;

a – the coefficient that determines the number of operable *SN*;

r – the reliability (probability of no–failure operation) of separate area of *SN*.

The biggest difficulty for building formulas (3) – is the definition of working condition SN, in other words the factors a. To this end is developed an algorithm that uses the «depth–first search», known from graph theory. For this is needed to renumber all areas of the structure from *1* to p. At each step, during each embranchment of decision graph is elected the plot, which together with other areas, which is selected at the previous stages, will create the part of constructive substructure. In the next step, this area is added to others has already selected and the process continues until substructure will be built. The areas are sorted in order of increasing their numbers. This makes fully and without repetition solving the problem. [1]

It is established that during the choice for the best reliability of water supply network of topological structure, should be used a point on the graph of function $R=f(r)$, which is determined of the maximum reliability r_{lim}. It must be chose that structure of water network, which has a minimum value of marginal reliability r_{lim} for a given geometric characteristics of the structure: the number of knots m, the number of structures n, the number of plots p.

The algorithm of the definition for the working condition *SN*:

Step 1. Renumber all areas of *SN*.

Step 2. Take a copy of the *SN* and remove from it the last section *lst* with the number *Nlst*. Calculate and memorize the a coefficient of substructures (*SS*) *SN*.

Step 3. Discard from substructure the last section *lst* and pass to the section with the previous number in *SN* to the number of rejected.

Step 4. If there is a plot *pst* with number *Npst* which is higher per unit of the number of *Nlst* rejected *lst*, then add *pst* to substructure.

Step 5. If there is no plot *pst* with number *Npst* which is higher per unit of the number of *Nlst* rejected *lst*, then discard *lst*. Go to the section with the previous number in the substructure relatival rejected. Calculate and remember the value coefficient of substructure. Go to step 4.

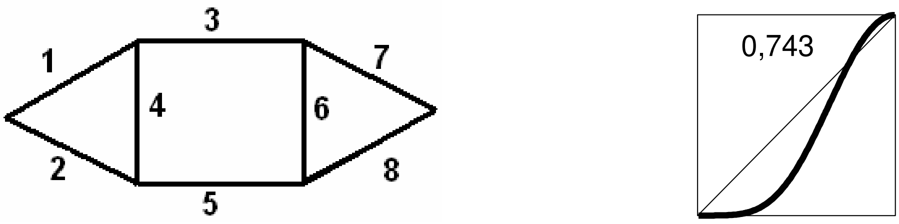
Step 6. As long as in the substructure are areas with greater numbers of the number of added plot, then sum these sections.

Step 7. If created substructure is not coherent and covering, then go to step 3.

Step 8. Calculate and remember the values of a of given substructure.

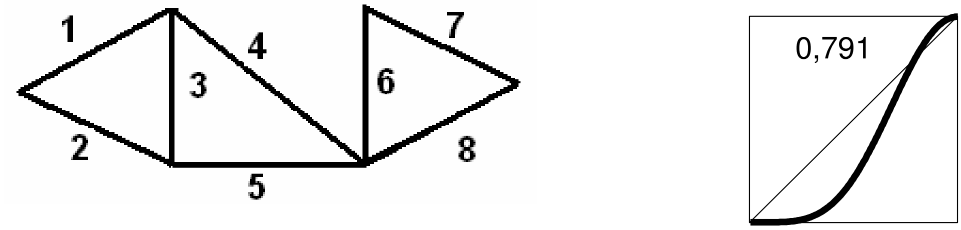
Step 9. If not exhausted all options of the substructure, go to the step 4.

The structures of the same numerical characteristics, but with the different topology. The structure of network (fig. 1 – 3) has the same number of: knots $m = 6$, sections $p = 8$, cycles $n = 3$.



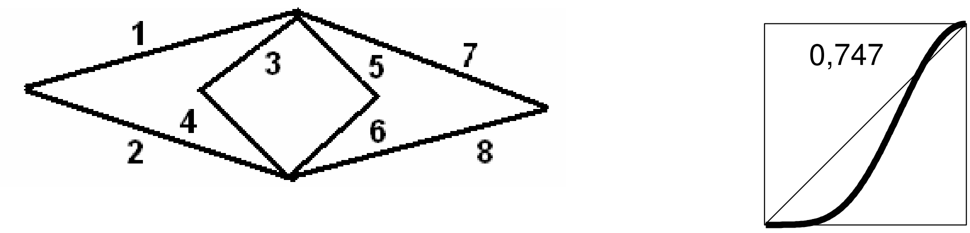
$R_1 = -12r^8 + 48r^7 - 65r^6 + 30r^5$ $r_{lim} = 0{,}743$

Figure 1 – The structure of the graph № 1 and the graph of reliability function SN № 1



$R_2 = -8r^8 + 34r^7 - 49r^6 + 24r^5$ $r_{lim} = 0{,}791$

Figure 2 – The structure of the graph № 2 and the graph of reliability function SN № 2

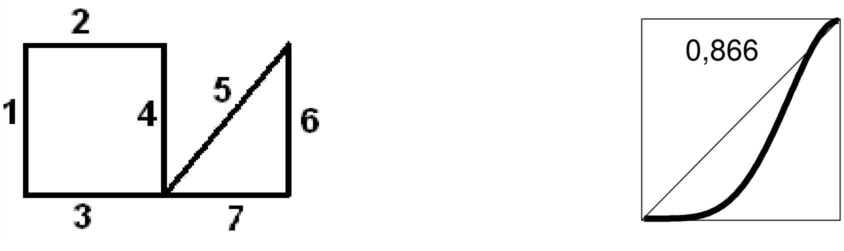


$R_3 = -15r^8 + 56r^7 - 72r^6 + 32r^5$ $r_{lim} = 0{,}747$

Figure 3 – The structure of the graph № 3 and the graph of reliability function SN № 3

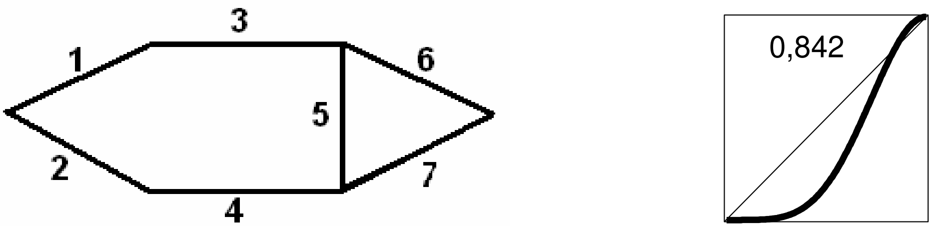
$$R_1 > R_3 > R_2 \ \forall r$$

The structure of network (fig. 4–6) has the same number of: knots $m = 6$, sections $p = 7$, cycles $n = 2$.



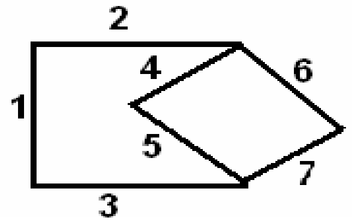
$R_4 = 6r^7 - 17r^6 + 12r^5$ $r_{lim} = 0{,}866$

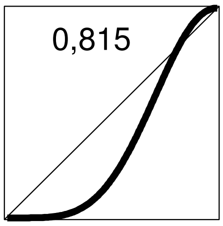
Figure 4 – The structure of the graph № 4 and the graph of reliability function SN № 4



$R_5 = 8r^7 - 21r^6 + 14r^5$ $r_{lim} = 0{,}842$

Figure 5 – The structure of the graph № 5 and the graph of reliability function SN № 5





$R_6 = 10r^7 - 25r^6 + 16r^5$ $r_{lim} = 0{,}815$

Figure 6 – The structure of the graph № 6 and the graph of reliability function SN № 6

$$R_6 > R_5 > R_4 \ \forall r$$

Conclusions. It was established that during the choice of the best of reliability of topological structure of pipeline network should use a point on the graph function *R=f(r)*, which determines the maximum reliability r_{lim}. It has been chosen that structure of water network, which has a minimum value of marginal reliability r_{lim} for a given geometric characteristics of structure: the number of knots *m*, the number of sections *n*, the number of cycles *p*.

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