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A.D. Taghiyeva

Sumgayit State University
Azerbaijan, AZ5008, Sumgayit, 43rd block,
tel: +994503887059; e-mail: aygun.taghiyeva.7@mail.ru

Approach to the solution of the optimum control problem of the water supply system

This paper considers the problem of optimal control of branched water supply systems. To control the system, the problem of optimal distribution of products is delivered whereas non-linear programming problems are applied. We consider a system for providing products, consisting of magistral and distribution pipelines, taking products from the magistral pipeline. Each distribution line has many warehouses. Products are taken into the system using the main intake facility and transferred between the warehouses using intermediate distribution facilities. To eliminate the deficiencies in management, tasks are set to determine the necessary intensities of product supply in the facilities, allowing timely provision of consumers with the necessary volume of products, to minimize losses, product discharges of facilities in the system during a certain control period.

Key words: water supply system, water supply line, water supply point, optimal control, water consumption, optimization criteria.

Introduction. The introduction of modern management systems in the water management provides enterprises with an unprecedented opportunity to control and manage all aspects of water intake, transportation, and distribution from a centralized management system. A approach for optimizing this system in real time is proposed, formulated as an integer quadratic programming problem. The proposed approach for solving this problem is very successful in achieving an almost optimal solution. Modern water management enterprises should be a single system, operating with information-computing system [1]. Benefits resulting from these actions can include improving the quality of water supply by reducing water loss, minimizing energy costs, and increasing system performance without compromising operational reliability. The real-time demand management strategy is applied to water supply enterprises to reduce the target cost function as low as possible [2].

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Characteristics of the object. In this work, we consider a product supply system, which consists of a main distribution line (ML) and K the number of distribution lines (DL) taking products from the ML. In each DL there are J_k number of warehouses (QW). Products are taken into the system with the help of the main fence (C-00) and transferred between the warehouses with the help of intermediate distribution structures (C_{kj} , $k = \overline{0, K}$, $j = \overline{1, J_k}$). Excessive products can be removed from the system using emergency facilities (C_{kJ_k}) at the end of each line. On each j -t section of the k line there are I_{kj} the number of consumers (T). To control such systems, the necessary intensities of product supply at each structure are calculated, which are supported by an automated control system [3]. It is important to focus on the intensity of water use, incorrect calculation of intensities generates large losses of water, energy and untimely provision of consumers [4]. Compression of the feed time interval results in a more accurate calculation of the intensity, which prevents large water losses, product dumps, unnecessary equipment switching. As a result, the efficiency of system management is increased.

Statement of the problem. It is required to find such intensities of supply of products in structures that can provide consumers with the necessary volume of products in a certain manner, minimize losses, product discharges and the number of changes in the operating modes of structures in the system during the control period (t_0, T) [5].

We divide the period (t_0, T) into Z the number of intervals $(t_{z-1}, t_z]$, on each of which the intensities are almost constant, $(t, T] = \bigcup_{z=1}^Z (t_{z-1}, t_z]$.

We use the following notation:

V_{kj}^z , $k = \overline{0, K}$, $j = \overline{1, J_k}$ – reserves of products in warehouses during the interval $(t_{z-1}, t_z]$;

Q_{kj}^z , $k = \overline{0, K}$, $j = \overline{0, J_k}$ – intensities of supply of products in line facilities;

q_{kji}^z , $k = \overline{0, K}$, $j = \overline{1, J_k}$, $i = \overline{1, I_{kj}}$ – intensities of consumption of products at points of consumption; C_{kJ_k} , $k = \overline{0, K}$ – penalties for dumping a unit volume of production;

C'_{kj} – penalties for losses of a unit volume of production in sections;

C_{kj} , $k = \overline{0, K}$, $j = \overline{0, J_k}$, $(kj) \neq (00)$ – penalties for supplying products in intermediate structures with a changed intensity. C'_{kj} for supplying products with an intensity different from, q_{kji}^{Tz} . Product losses in the areas taken propor-

tional to stock products in which $Q_{kj}^{pot,z} = L_{kj}V_{kj}^z$, $k = \overline{0, K}$, $j = \overline{0, J_k}$ where L_{kj} – proportionality factor.

As the objective function, the sum of the costs associated with the discharge of products from the automation system $Q_{kJ_k}^z$, with consumption, losses in the areas $L_{kj}V_{kj}^z$ and, with the squares of the flow rate change in C_{kj} ($Q_{kj}^z - Q_{kj}^{z-1}$) and T_{kj} ($q_{kji}^{Tz} - q_{kji}^z$):

$$f = \sum_{z=1}^Z \sum_{k=0}^K C_{kJ_k} Q_{kJ_k}^z \Delta t_z + \sum_{z=1}^Z \sum_{k=0}^K \sum_{j=1}^{J_k} C'_{kj} L_{kj} V_{kj}^z \Delta t_z + \\ + \sum_{z=1}^Z \sum_{k=0}^K \sum_{j=0}^{J_k-1} C_{kj} [(Q_{kj}^z - Q_{kj}^{z-1}) \Delta t_z]^2 + \sum_{z=1}^Z \sum_{k=0}^K \sum_{j=1}^{J_k} \sum_{i=1}^{I_{kji}} C_{kji} [(q_{kji}^z - q_{kji}^{Tz}) \Delta t_z]^2 \rightarrow \min.$$

Here Z is the number of time intervals; K is the number of lines; J - the number of warehouses in one line; I - the number of consumers of one line.

Denote

$$C_{00}^z = C_{00} \Delta t_z, C_{kJ_k}^z = C_{kJ_k} \Delta t_z, C_{kj}^{pot,z} = C'_{kj} L_{kj} \Delta t_z, \\ C_{kj}^z = C_{kj} \Delta t_z^2, C_{kji}^z = C_{kji} \Delta t_z.$$

Then the objective function is transformed to the form:

$$f = \sum_{z=1}^Z \sum_{k=0}^K C_{kJ_k}^z Q_{kJ_k}^z + \sum_{z=1}^Z \sum_{k=0}^K \sum_{j=1}^{J_k} C_{kj}^{pot,z} Q_{kj}^{it,z} + \sum_{z=1}^Z \sum_{k=0}^K \sum_{j=0}^{J_k-1} C_{kj}^z (Q_{kj}^z - Q_{kj}^{z-1})^2 + \\ + \sum_{z=1}^Z \sum_{k=0}^K \sum_{j=1}^{J_k} \sum_{i=1}^{I_{kji}} C_{kji}^z (q_{kji}^z - q_{kji}^{Tz})^2 \rightarrow \min. \quad (1)$$

The following restrictions apply:

The relationship between the change in stock of products and the balance of consumption in the sections of lines:

For DL

$$V_{kj}^z - V_{kj}^{z-1} = \Delta t_z \left(Q_{k,j-1}^z - \sum_{i=1}^{I_{kji}} q_{kji}^z - Q_{kj}^z - 0.5 L_{kj} (V_{kj}^z + V_{kj}^{z-1}) \right), \quad (2) \\ k = \overline{K, 1}, j = \overline{J_k, 1}, z = \overline{1, Z}.$$

For TL

$$V_{0j}^z - V_{0j}^{z-1} = \Delta t_z \left(Q_{0,j-1}^z - \sum_{i=1}^{I_{kji}} q_{0ji}^z - \sum_{k \in K_j} Q_{k0}^z - Q_{0j}^z - 0.5 L_{0j} (V_{0j}^z + V_{0j}^{z-1}) \right), \quad (3)$$

$$j = \overline{J_0, 1}, z = \overline{1, Z}.$$

Here K_j is the set of DL numbers taking products from ML.

Limitations on volumes and expenses of products on the sections of lines:

$$V_{kj}^{\min} \leq V_{kj}^z \leq V_{kj}^{\max}, \quad k = \overline{0, K}, j = \overline{1, J_k}, z = \overline{1, Z}; \quad (4)$$

$$0 \leq Q_{kj}^z \leq Q_{kj}^{\max}, \quad k = \overline{0, K}, j = \overline{0, J_k}, z = \overline{1, Z}; \quad (5)$$

$$0 \leq q_{kji}^z \leq q_{kji}^{\max}, \quad k = \overline{0, K}, j = \overline{1, J_k}, z = \overline{1, Z}. \quad (6)$$

Problem (1)–(6) is a quadratic programming problem [6]. The constraint (2) and (3) are given in implicit form, and (4), (5) and (6) in explicit form. To solve this problem, let us estimate the number of parameters and constraints. For this purpose, we will accept the following designations:

$$E_1 = Z \sum_{k=0}^K J_k, \quad E_2 = E_1 + Z \sum_{k=0}^K (J_k + 1), \quad E_3 = E = E_2 + Z \sum_{k=0}^K \sum_{j=1}^{J_k} I_{kj},$$

or

$$\begin{aligned} E &= Z \sum_{k=0}^K J_k + Z \sum_{k=0}^K (J_k + 1) + Z \sum_{k=0}^K \sum_{j=1}^{J_k} I_{kj}; \\ P_1 &= Z \sum_{k=1}^K J_k, \quad P_2 = P_1 + ZJ_0, \quad P_3 = P_2 + Z \sum_{k=0}^K J_k, \quad P_4 = P_3 + Z \sum_{k=0}^K J_k, \\ P_5 &= P_4 + Z \sum_{k=0}^K (J_k + 1), \quad P_6 = P_5 + Z \sum_{k=0}^K (J_k + 1), \quad P_7 = P_6 + Z \sum_{k=0}^K \sum_{j=1}^{J_k} I_{kj}, \\ P_8 &= P = P_7 + Z \sum_{k=0}^K \sum_{j=1}^{J_k} I_{kj}, \text{ or } P = 5Z \sum_{k=0}^K J_k + 2Z(K + 1) + 2Z \sum_{k=0}^K \sum_{j=1}^{J_k} I_{kj}, \quad (7) \end{aligned}$$

where E is the number of parameters; P is the number of restrictions. In view of (7), we denote $x = (x_e^{(1)}, x_e^{(2)}, x_e^{(3)}) = \{x_e, e = \overline{1, E}\}$. Here

$$x_e^{(1)} = V_{kj}^z, \quad e = \overline{1, E_1}; \quad x_e^{(2)} = Q_{kj}^z, \quad e = \overline{E_1 + 1, E_2};$$

$$x_e^{(3)} = q_{kji}^z, \quad e = \overline{E_2 + 1, E}.$$

We denote explicit restrictions in a similar way:

$$b = (b_p^{(3)}, b_p^{(4)}, b_p^{(5)}, b_p^{(6)}, b_p^{(7)}, b_p^{(8)}),$$

$$\begin{aligned} b_p^{(3)} &= V_{kj}^{\max}, \quad p = \overline{P_2 + 1, P_3}; \quad b_p^{(4)} = 0, \quad p = \overline{P_3 + 1, P_4}; \\ b_p^{(5)} &= Q_{kj}^{\max}, \quad p = \overline{P_4 + 1, P_5}; \quad b_p^{(6)} = 0, \quad p = \overline{P_5 + 1, P_6}; \\ b_p^{(7)} &= q_{kji}^{\max}, \quad p = \overline{P_6 + 1, P_7}; \quad b_p^{(8)} = 0, \quad p = \overline{P_7 + 1, P}. \end{aligned}$$

The restrictions can be written as follows:

$$\begin{aligned} g_p^{(1)} &= V_{kj}^z - V_{kj}^{z-1} - \Delta t_z \left(Q_{k,j-1}^z - \sum_{i=1}^{I_{kj}} q_{kji}^z - Q_{kj}^z - 0.5 L_{kj} (V_{kj}^z + V_{kj}^{z-1}) \right) = 0, \\ k &= \overline{K, 1}, \quad j = \overline{J_k, 1}, \quad z = \overline{1, Z}, \quad p = (z-1) \sum_{n=K}^1 J_{n_1} + \sum_{n=K}^k J_n + 1 - j, \quad p = \overline{1; P_1}; \\ g_p^{(2)} &= V_{0j}^z - V_{0j}^{z-1} - \Delta t_z \left(Q_{0,j-1}^z - \sum_{i=1}^{I_{0j}} q_{0ji}^z - Q_{0j}^z - \sum_{k \in K_j} Q_{k0}^z - L_{0j} V_{0j}^z \right) = 0, \\ j &= \overline{J_0, 1}, \quad z = \overline{1, Z}, \quad p = P_1 + (z-1) J_0 + J_0 + 1 - j, \quad p = \overline{P_1 + 1, P_2}; \\ g_p^{(3)} &= V_{kj}^z \leq b_p^{(3)}, \quad k = \overline{0, K}, \quad j = \overline{1, J_k}, \quad z = \overline{1, Z}, \\ p &= P_2 + (z-1) \sum_{k=0}^K J_k + \sum_{n=0}^k J_{n-1} + j, \quad (J_{-1} = 0), \quad p = \overline{P_2 + 1, P_3}; \\ g_p^{(4)} &= -V_{kj}^z \leq b_p^{(4)}, \quad k = \overline{0, K}, \quad j = \overline{1, J_k}, \quad z = \overline{1, Z}, \\ p &= P_3 + (z-1) \sum_{k=0}^K J_k + \sum_{n=0}^k J_{n-1} + j, \quad (J_{-1} = 0), \quad p = \overline{P_3 + 1, P_4}; \\ g_p^{(5)} &= Q_{kj}^z \leq b_p^{(5)}, \quad k = \overline{0, K}, \quad j = \overline{0, J_k}, \quad z = \overline{1, Z}, \\ p &= P_4 + (z-1) \sum_{k=0}^K (J_k + 1) + \sum_{n=0}^k (J_{n-1} + 1) + 1 + j, \quad (J_{-1} = 0), \quad p = \overline{P_4 + 1, P_5}; \\ g_p^{(6)} &= -Q_{kj}^z \leq b_p^{(6)}, \quad k = \overline{0, K}, \quad j = \overline{0, J_k}, \quad z = \overline{1, Z}, \\ p &= P_5 + (z-1) \sum_{k=0}^K (J_k + 1) + \sum_{n=0}^k (J_{n-1} + 1) + 1 + j, \quad (J_{-1} = 0), \quad p = \overline{P_5 + 1, P_6}; \\ g_p^{(7)} &= q_{kji}^z \leq b_p^{(7)}, \quad k = \overline{0, K}, \quad j = \overline{1, J_k}, \quad i = \overline{1, I_{kj}}, \quad z = \overline{1, Z}, \\ p &= P_6 + (z-1) \sum_{k=0}^K \sum_{j=1}^{J_k} I_{kj} + \sum_{n=0}^{k-1} \sum_{m=1}^{J_k} I_{nm} + \sum_{m=1}^j I_{k,m-1} + i, \quad p = \overline{P_6 + 1, P_7}; \end{aligned}$$

$$g_p^{(8)} = -q_{kji}^z \leq b_p^{(8)}, \quad k = \overline{0, K}, \quad j = \overline{1, J_k}, \quad z = \overline{1, Z},$$

$$p = P_7 + (z-1) \sum_{n=0}^k \sum_{j=1}^{J_k} I_{nj} + \sum_{m=1}^j I_{k,m-1} + i, \quad (I_{k0} = 0), \quad p = \overline{P_7 + 1, P_8}.$$

Given the notation (7), the total number of control parameters and restrictions will be as follows:

$$E = Z \sum_{k=0}^K J_k + Z \sum_{k=0}^K (J_k + 1) + Z \sum_{k=0}^K \sum_{j=1}^{J_k} I_{kj},$$

$$P = 5Z \sum_{k=0}^K J_k + 2Z(K+1) + Z \sum_{k=0}^K \sum_{j=1}^{J_k} I_{kj}.$$

Suppose that on each line there are J number of sections and each section has I number of points of consumption. Then the number of parameters and

Table 1. Number of parameters and restrictions

Z	K	J	I	E	P
1	1	1	1	8	16
1	2	2	2	27	48
1	3	3	1	40	80
1	3	3	2	52	92
2	1	1	1	16	32
2	2	2	2	54	96
2	2	3	1	60	120
2	2	3	2	78	138
2	3	3	2	104	184
3	1	1	1	24	48
3	2	2	2	81	144
3	2	3	2	117	207
3	3	3	2	156	276
4	1	1	1	32	64
4	2	2	2	108	192
4	2	3	2	156	276
4	3	3	2	208	368
5	1	1	1	40	80
5	2	2	2	135	240
5	2	3	2	195	345
5	3	3	2	260	460

Distributed support system

Table 2. Results of Problem Solving

$(t_0, T]$, min	Variable	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	X ₁₁
Parameters		Q_{00}	Q_{01}	Q_{02}	Q_{10}	Q_{11}	Q_{12}	Q_{20}	Q_{21}	Q_{22}	q_{011}	q_{021}
Lower border		0	0	0	0	0	0	0	0	0	0	0
Upper border		10	6	3	4	4	3	4	3	3	2	2
Start value		7	4	0.1	2.5	1.3	0.1	2.5	1.0	0.1	1.3	1.2
30	10	7	3.62	0	2.5	1.3	0	2.5	1.1	0	1.3	1.2
	20	7.21	3.12	0	2.34	1.3	0	2.5	1.1	0	1.3	1.2
	30	7.07	3.72	0	2.22	1.3	0	2.5	1.1	0	1.3	1.2
45	15	7.05	3.62	0	2.45	1.3	0	2.5	1.1	0	1.3	1.2
	30	7.17	3.62	0	2.22	1.3	0	2.4	1.19	0	1.3	1.2
	45	6.9	3.54	0	2.22	1.3	0	2.4	0.92	0	1.3	1.2
60	20	7.1	3.62	0	2.37	1.3	0	2.5	1.1	0	1.3	1.2
	40	7.2	3.52	0	2.22	1.3	0	2.3	1.05	0	1.3	1.2
	60	6.9	3.36	0	2.22	1.3	0	2.24	0.92	0	1.3	1.2
90	30	7.16	3.62	0	2.29	1.3	0	2.5	1.1	0	1.3	1.2
	60	6.9	3.35	0	2.22	1.3	0	2.13	0.92	0	1.3	1.2
	90	6.7	3.36	0	2.15	1.23	0	2.14	0.92	0	1.3	1.2
180	60	16.9	13.5	0	2.2	1.3	0	12.4	0.96	0	1.3	1.2
	120	-2.5	-6.3	0	2.2	1.18	0	7.64	0.82	0	1.3	1.2
	180	6.73	3.26	0	2.12	1.22	0	2.13	0.92	0	1.3	1.2
270	90	16.7	13.4	0	2.1	1.2	0	12.3	0.91	0	1.3	1.2
	180	-2.3	-6.1	0	2.21	1.23	0	-7.4	0.82	0	1.3	1.2
	270	6.75	3.27	0	2.15	1.23	0	2.13	0.91	0	1.3	1.2

End of the table 2

$(t_0, T]$, min	Variable	X ₁₂	X ₁₃	X ₁₄	X ₁₅	X ₁₆	X ₁₇	X ₁₈	X ₁₉	X ₂₀	X ₂₁
Parameters		q_{111}	q_{112}	q_{121}	q_{211}	V_{01}	V_{02}	V_{11}	V_{12}	V_{21}	V_{22}
Lower border		0	0	0	0	1500	1500	1500	1000	1000	1000
Upper border		2	2	2	2	2500	2000	2000	2000	2000	2000
Start value		7	1.2	1.2	1.2	2000	2000	1700	1500	1500	1500
30	10	0.9	1.2	1.2	0.9	1725.6	1940.2	1869.3	1550.8	1610.7	1610.7
	20	0.9	1.2	1.2	0.9	1519.3	1940.2	1940.2	1601.4	1720.7	1720.7
	30	0.9	1.2	1.2	0.9	1500	1940.2	1940.2	1651.6	1830.0	1830.0
45	15	0.9	1.2	1.2	0.9	1678.2	1910.4	1910.4	1576.2	1665.8	1665.8
	30	0.9	1.2	1.2	0.9	1679.1	1910.4	1910.4	1651.6	1660.0	1910.4
	45	0.9	1.2	1.2	0.9	1500	1841.8	1910.4	1726.4	1896.8	1910.4
60	20	0.9	1.2	1.2	0.9	1737.2	1880.7	1880.7	1601.4	1720.7	1720.7
	40	0.9	1.2	1.2	0.9	1856.3	1881.4	1880.7	1701.6	1751.4	1881.4
	60	0.9	1.2	1.2	0.9	1835.7	1769.0	1880.7	1800.6	1877.3	1881.4
90	30	0.9	1.2	1.2	0.9	1853.6	1821.6	1821.6	1651.6	1836.9	1823.2
	60	0.9	1.2	1.2	0.9	1853.8	1821.6	1821.6	1800.6	1827.5	1823.2
	90	0.9	1.2	1.2	0.9	1594	1817	1826.1	1822.7	1839.3	1823.2
180	60	0.9	1.2	1.2	0.9	1500	1500	1650	1800.6	37499.2	2000
	120	0.9	1.2	1.2	0.9	2500	2000	1994.2	1652.6	2000	1652.6
	180	0.9	1.2	1.2	0.9	2479.8	1680.6	1942.5	1651.7	1994.3	1652.6
270	90	0.9	1.2	1.2	0.9	1500	1500	1500	1421.1	54388	2000
	180	0.9	1.2	1.2	0.9	2500	2000	1887	1484.7	2000	1488
	270	0.9	1.2	1.2	0.9	2438.2	1562.6	1945.5	1886.2	1987.7	1488

restrictions will be as follows:

$$E = Z(K+1)J + Z(K+1)(J+1) + Z(K+1)JI = Z(K+1)(2J+1+JI),$$

$$P = 5Z(K+1)J + 2Z(K+1) + Z(K+1)JI = Z(K+1)(5J+2+JI). \quad (8)$$

Based on (8), we obtain the values indicated in Table. 1, from which it can be seen that when solving problem (1)–(6), we obtain too many control parameters and constraints. Therefore, it is necessary to develop a simpler and more effective solution to the problem [7].

The solution of the problem (1)–(6) has been solved for a system consisting of ML and two DL powered by ML. Each line consists of two sections, one consumer in each (look Fig.). The control period is divided into three consecutive intervals and the mathematical formulation of the problem is obtained in the following form:

$$f = \sum_{z=1}^3 \sum_{k=0}^2 C_{k2} Q_{k2}^z \Delta t_z + \sum_{z=1}^3 \sum_{k=0}^2 \sum_{j=1}^2 C_{kj}^{'z} L_{kj} V_{kj}^z + \sum_{z=1}^3 \sum_{k=0}^2 \sum_{j=0}^2 C_{kj}^z (Q_{kj}^z - Q_{kj}^{z-1})^2 +$$

$$+ \sum_{z=1}^3 \sum_{k=0}^2 \sum_{j=1}^2 C_{kji}^z (q_{kji}^z - q_{kji}^{Tz})^2 \rightarrow \min. \quad (9)$$

$$V_{kj}^z - V_{kj}^{z-1} = \Delta t_z (Q_{k,j-1}^z - q_{kj1}^z - Q_{kj}^z - 0.5 L_{kj} (V_{kj}^z + V_{kj}^{z-1})),$$

$$k = \overline{2, 1}, j = \overline{2, 1}, z = \overline{1, 3}; \quad (10)$$

$$V_{0j}^z - V_{0j}^{z-1} = \Delta t_z (Q_{0,j-1}^z - q_{0j1}^z - Q_{0j}^z - 0.5 L_{0j} (V_{0j}^z + V_{0j}^{z-1})),$$

$$j = \overline{2, 1}, z = \overline{1, 3}; \quad (11)$$

$$V_{kj}^{\min} \leq V_{kj}^z \leq V_{kj}^{\max}, \quad k = \overline{0, 2}, j = \overline{1, 2}, z = \overline{1, 3}; \quad (12)$$

$$0 \leq Q_{kj}^z \leq Q_{kj}^{\max}, \quad k = \overline{0, 2}, j = \overline{0, 2}, z = \overline{1, 3}; \quad (13)$$

$$0 \leq q_{kji}^z \leq q_{kji}^{\max}, \quad k = \overline{0, 2}, j = \overline{1, 2}, z = \overline{1, 3}. \quad (14)$$

Computer implementation of the solution is made in the C++ programming environment. The results are presented in table. 2, from which it can be seen that in problem (9)—(14) the number of variables is 21 (taking into account the time intervals), the total number of variables is 63, and the number of constraints is 144. The problem is solved using the Hook-Jeeves method subject to constraints [8].

Conclusion

From the table 2 shows that when solving the problem at large intervals, the values of some parameters go beyond the boundary values. Therefore, when solving the problem, the intervals of constancy of parameters should be chosen relatively short. But in this case, when solving the problem for all intervals at the same time, the number of parameters and constraints increases significantly. As a result, the solution to the problem is complicated. In order to simplify, the problem can be solved sequentially for each interval and relate the results obtained in real time. In this case, it is necessary to study the deviation of the obtained solutions from their optimal values. Based on the analysis of the results, you can choose the best option for determining the length of time intervals.

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A.D. Taghiyeva

ПІДХІД ДО РОЗВ'ЯЗКУ ЗАДАЧІ ОПТИМАЛЬНОГО УПРАВЛІННЯ СИСТЕМОЮ ВОДОЗАБЕЗПЕЧЕННЯ

Розглянуто задачу оптимального управління розгалуженими системами водозабезпечення. Для розв'язку задачі застосовано методи нелінійного програмування. Система містить магістральну та розподільчу лінії. Кожна розподільча лінія має велику кількість складів. Продукція між ними передається за допомогою проміжних розподільчих споруд. Поставлено та розв'язано задачу визначення потужності подачі продукції у спорудах, яка необхідна для своєчасного забезпечення споживачів потрібним об'ємом продукції та для максимального зменшення втрат впродовж певного періоду.

К л ю ч о в і с л о в а: система водозабезпечення, пункт водоспоживання, оптимальне управління, витрати води, критерій оптимізації.

TAGHIYEVA Aygun Damir, post-graduate of the Sumgayit State University. Graduated from the Azerbaijan State Institute of Oil and Chemistry in 1990. Sphere of scientific research: developing models to meet water supply needs.