BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 64 (68), Numărul 2, 2018
Secţia
CONSTRUCŢII DE MAŞINI

STUDY OF REQUIRED REHABILITATION OF PUMP STATIONS

BY

AURORA ALEXANDRESCU*

“Gheorghe Asachi” Technical University of Iaşi, Romania,
Faculty of Machine Manufacturing and Industrial Management

Received: June 15, 2018
Accepted for publication: August 29, 2018

Abstract. The paper aims to carry out a study on reducing the m^3 of drinking water supplied to industrial and household consumers, while reducing electricity consumption. The elements of a hydraulic system for transport, distribution, control of drinking water, as well as the mutual interaction and influence between them, were highlighted; the operation of pumps in transmission and distribution network was studied. The method for optimizing the operation of the pumping station assembly - the distribution transmission network has two objective functions: the total cost of the investment for rehabilitation along with the operating costs (minimum must be) and the total efficiency (must be maximum). It is necessary for every active consumer in the network to obtain for the period of 24 hours minimum conditions provided by the legislation in force with a minimum price of m^3 of drinking water. The proposed optimization method is applied in the calculation programs TriProgPomp for MATLAB, TrasareCarAn for MATLAB, CSHUP for MATLAB, DetDebitSA for MATLAB registered with the Romanian Office for Copyright ORDA, series S5001351 no. 04 518/30.11.2010. These computational programs have been developed by the author of this paper. The method of study used is applied to the pumping station CUG Iași, Romania.

Keywords: flow; pressure; pipeline network; hydraulic losses; total efficiency.

*Corresponding author; *e-mail*: alexandrescuaurora@gmail.com

1. Introduction

In the context of increasing urban agglomeration, effective management of drinking water resources is required. Upgrading of all distribution networks in hydraulic systems is required. It is aimed at optimizing the complex drinking water supply systems by taking into account the water loss reductions and reducing the energy consumption necessary for the system operation (Gama *et al.*, 2015).

Optimizing the operation of the pumping station assembly - distribution network - tanks is essential for the efficient use of hydraulic drinking water systems. The aim is to reduce the electricity consumption by reducing the running time of the pumps (Bagirov *et al*., 2013).

Particular importance must be attached to the reduction of carbon emissions in the atmosphere. This requires reducing the power consumption required for the operation of a pumping station. An original method is proposed to optimize the operation of a pumping station by imposing efficient computer programs on their operation; computer programs simultaneously aim at reducing electricity consumption and reducing the overall cost of running the entire hydraulic system (Cherchi *et al.*, 2015).

Another approach to hydraulic systems is to reduce the costs involved in capturing, treating, pumping, transporting and distributing water. Different variants are studied which include reducing or not energy consumption for these complex systems (Coelho and Andrade-Campos, 2014).

An original method to optimize the operation of pumping stations proposes a mathematical model of water height programming in the suction tank of two parallel pumping stations. It is intended to obtain an optimal flow of water supplied in the distribution system by each pumping station by taking into account the consumption by the users. It is also intended that the total cost of pumping and water distribution be optimal (Gong *et al.*, 2014).

Starting from the idea that the operation of each pumping station is unpredictable, an original method of optimizing the operation of a hydraulic system is proposed. Variable water demand by active consumers in the distribution network is taken into account. The mathematical method proposes a linear programming model for a hydraulic system composed of one or two pumping stations (Goryashko and Nemirovski, 2014).

In optimizing the operation of a pumping station, efficient linear and nonlinear programming methods should be used. Linear and local pressure losses across the hydraulic system are taken into account. Particular importance is given to water losses in distribution transmission networks and the total energy consumption needed to pump water into the hydraulic system. To meet these conditions, different optimization models and algorithms are proposed (Price and Ostfeld, 2014).

The development of a hydraulic modelling method of water supply systems adapted for design, research and exploitation aims to determine the operating schedule of pump aggregates leading to minimal operating costs. The model can be updated easily. This method involves the use of the following software: Excel, Autocad, EpaCAD, Matlab and EPANET. The programs can be generalized and applied to any water supply system. The operation of pumps after a program obtained with an optimization algorithm leads to lower operating costs than their control depending on the water level in the discharge tanks. The main problem that can be encountered in such an approach is the variation in water consumption over time and space (Miron, 2013).

2. Materials and Methods

The CUG pumping station is located in the Moldavian Plain, Lower Jijia Plain Sub - Region, the Bahlui Corridor, at the foot of the south - eastern slope of the Miroslava Hill, on the right side of the Nicolina Stream, at a level of 48.8 m above sea level. Aspiration of the 2 NDS type eight pumps is made from a 103 m^3 tank located at a distance of 15 m from the pumping station building; this tank is fed from the distribution network of the city of Iasi, and from pumping station Chirița. The tank is powered on a single wire with Dn 400 mm; at the diametrically opposed end are mounted 4 float valves with Dn 150 mm each. The over - full Dn 400 mm duct aspirates by gravity flow to the outside duct when the maximum tank level is exceeded in the event of failure of one of the float valves. The drain is made of wrinkles.

The CUG pumping station supplies a 5000 m^3 tank in the Miroslava locality, with a 108.65 m elevation (Fig. 1).

The existing pumping station ensures the raising of drinking water pressure for the water supply of the Nicolina CUG Iași residential area. Technological installations are designed for the nominal station flow rate Q_{max} = 173 l/s = 0.173 m^3/s = 623 m^3/h. The pumping equipment consists of 2 NDS pumps (NDS 250 - 200 - 510) with a nominal speed of n = 1500 rpm, a head of H = 72 m, a flow rate Q = 500 m^3/h and a power P = 160 kW. Of the two pumps, only one is used to supply the tank to the Miroslava, while the second pump is reserve; each pump can fill the tank in six hours of operation, with an average flow of approx. $Q_{average}$ = 840 m^3/h.

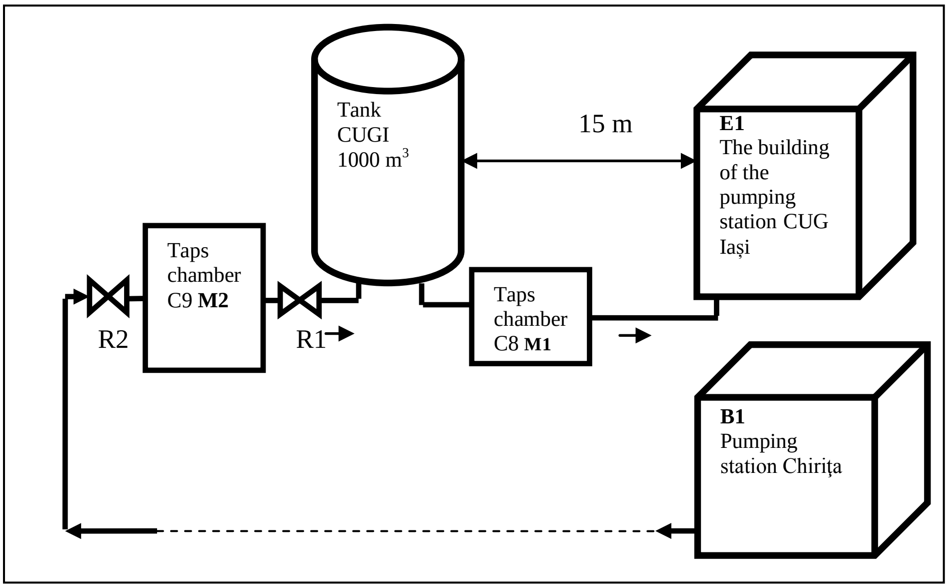

Fig. 1 – Scheme for the installation of the suction tank and the pumping station CUG Iași.

According to the situation plan provided by S.C. APAVITAL Iași, the head characteristics of the distribution transmission networks were calculated.

Calculate the two geometric heads, minimum $H_{g\ max}$ = 71.4 m and maximum $H_{g\ min}$ = 63.673 m (Fig. 2).

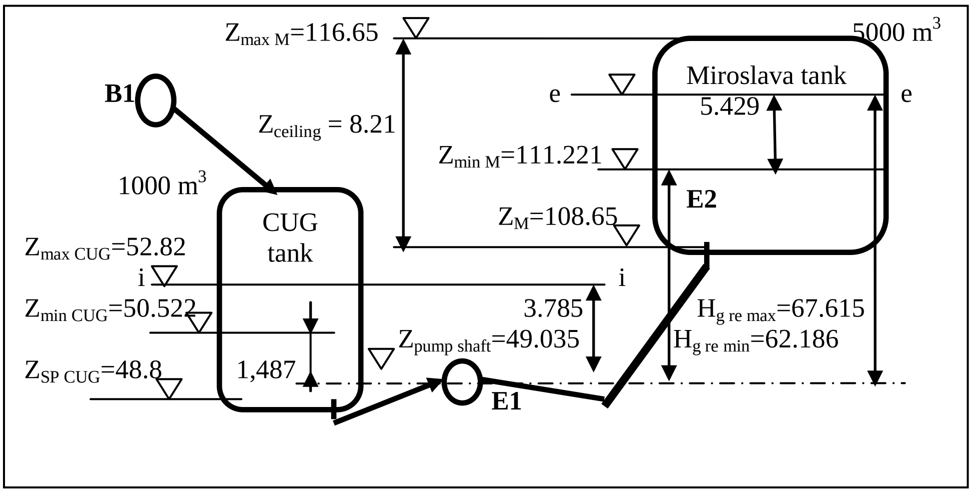

Fig. 2 – Scheme for calculating the load characteristics of the pipeline network fed by the CUG Iași pumping station before rehabilitation.

Calculate the head characteristics of the drinking water distribution network for the minimum static head $H_{R\ \min\ P1,\ (P2)}$, [m] and the maximum $H_{R\ \max\ P1,\ (P2)}$, [m] when the hydraulic system is fed to the station pumping CUG Iași to pumps P1 or P2.

The determination of the operating points for the experimental variant (using the head characteristics of the pumps obtained by measurements at the CUG Iași pumping station) and the theoretical (using the catalogue characteristics for the NDS pump 8 at the CUG Iași pumping station) is shown in Fig. 3.

Eight pump variants were analyzed for the replacement of the 8 NDS pumps in SP CUG Iasi, in order to rehabilitate the station: 1) the Wilo IL 250 - 200/4 pump; pump 2) Wilo IL 250 - 160/4; 3) pump CPK, CPKN, HPK 200-500 with diameters of 460 mm and 480 mm, KSB; 4) NB pump, NK 150-500 / 489, 4 poles, frequency 50 Hz; 5) NBG / NKG 150-125-250 / 248, 2-pole pump; 6) NB, NK 150-125-250 / 248, 2 poles; 7) pump CPK, CPKN, HPK 200-500 / 460, KSB; 8) pump CPK, CPKN, HPK 200-500 / 480, KSB.

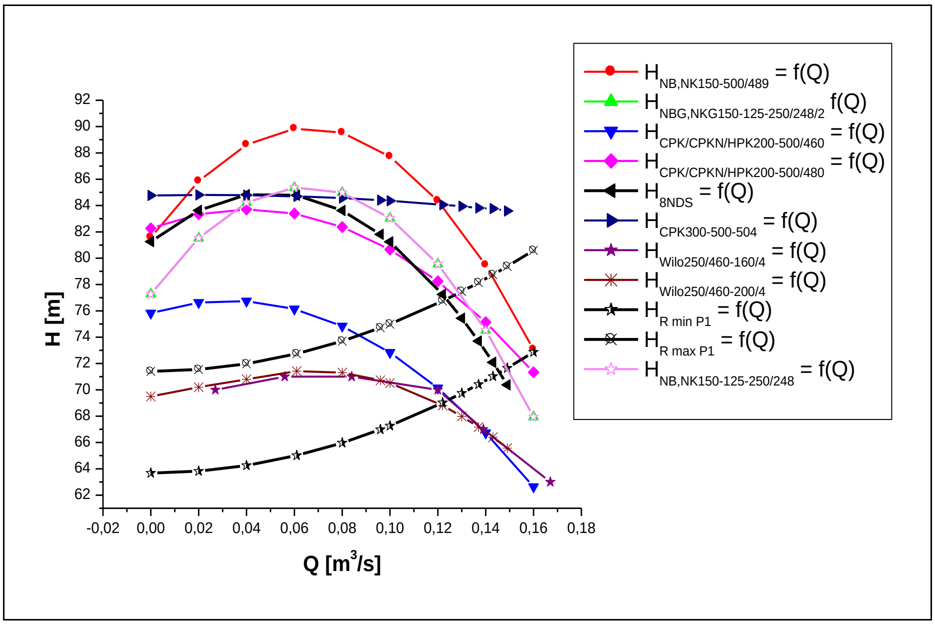

Fig. 3 – The analysis of the operating areas through the intersection of the head characteristics of the pump *H* by the flow rate *Q*, *H* = f (*Q*) for all eight pump variants chosen for the 8NDS pump replacement, with the head characteristics of the distribution network with two static heads, minimum $H_{R\ \min\ P1}$ and maximum $H_{R\ \max\ P1}$ for P1 pump operation.

In order to be able to choose the best option for the pumping station in the rehabilitation, the functional parameters for the eight pump variants chosen with the current 8NDS pump variant were compared. The original analysis and graphics programs TriProgPomp for MATLAB, TrasareCarAn for MATLAB, CSHUP for MATLAB, DetDebitSA for MATLAB (Romanian Office for Copyright ORDA, S5001351 series No. 04 518/30.11.2010; these calculation programs have been made by the author of this paper) were used to determine the variations of the following functional parameters defining the pump assembly - the drinking water distribution network:

1) Head characteristic of the pump *H*, [m], according to the volume flow *Q*, [m^3/s] H = f (Q), the charging characteristic of the drinking water distribution network for the minimum static head $H_{R\ \min\ P1}$, [m], and the maximum $H_{R\ \max\ P1}$, [m], depending on the volumetric flow *Q*, $H_{R\ \min\ P1}$ = f (Q), $H_{R\ \max\ P1}$ = f (Q), for the operation of pump P1 in the hydraulic system (Fig. 3).

2) The pump efficiency characteristic η, [%], on the volume flow *Q*, [m^3/s], η = f (Q) (Fig. 4).

3) Hydraulic power characteristic of the pump *P*, [kW], according to the volumetric flow *Q*, [m^3/s], P = f (Q) (Fig. 5).

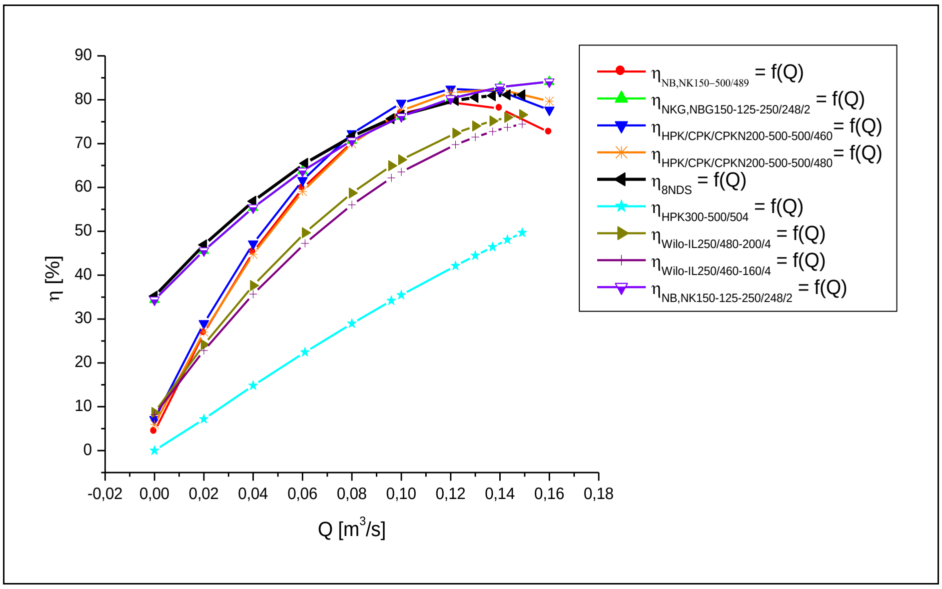

Fig. 4 – Analysis of variation of pump efficiency η on the volume flow *Q*, η = f (Q) for all eight pump variants chosen for 8NDS pump replacement, by rehabilitation of SP CUG Iași.

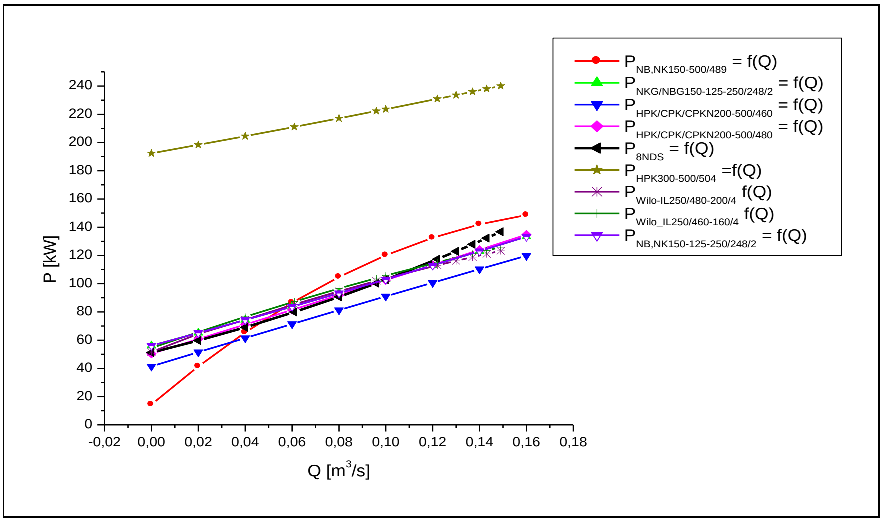

Fig. 5 – Analysis of the hydraulic power variation of the pump *P* according to the volume flow *Q*, *P* = f (*Q*) for all eight pump variants chosen for 8NDS pump replacement, by rehabilitation of SP CUG Iaşi.

4) The Net Positive Suction Head *NPSH*, [m], of pumps according to volume flow *Q*, [m^3/s], *NPSH* = f (*Q*) (Fig. 6).

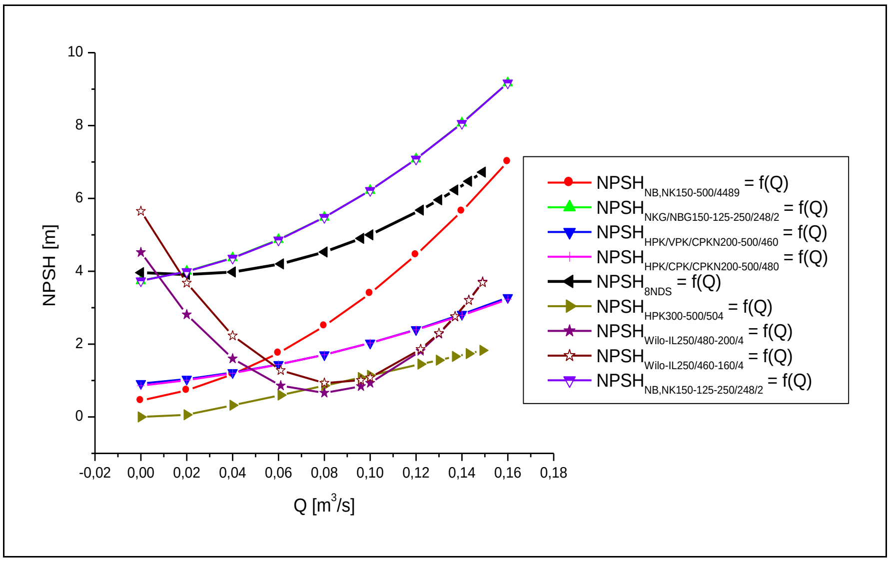

Fig. 6 – Pump Net Positive Suction Head *NPSH* depending on volume flow *Q* analysis, *NPSH* = f (*Q*), for all eight pump variants chosen for 8NDS pump replacement by SP CUG Iaşi rehabilitation.

3. Results and Discussion

Was analyzed the behavior of the two pumps P1 and P2 in operation and according to the catalog; was determined the operating points for the pump - the drinking water distribution network assembly: the volume flow from the operating point Q_{pf}, [m^3/s] and the load point of the H_{pf}, [m] when using the two extreme head characteristics for the distribution network $H_{R\,\max P1,\,(P2)}$, [m] and $H_{R\,\min P1,\,(P2)}$, [m]; the practical results are shown in Table 1.

From the comparison of the functional parameter values corresponding to the experimental and theoretical functional points (catalogue), the wear of the two pumps is clearly observed; all experimental functional parameters are much lower than those in the catalogue.

From the study and comparison of the experimental and catalogue data for the pumping units for the pumping station CUG Iași, it is found that these do not correspond hydraulically and should be replaced. The head provided by the CUG pumping station is the largest in the analyzed hydraulic system, ranging from H_{E1} (71.2 ÷ 76.9) m (Fig. 2); the Miroslava tank is fed to a 108.65 m land area and the CUG domestic and industrial consumers in the D. Cantemir, Ţuţora, Galata, Frumoasa, Ciurea neighbourhoods are relatively large. The free level of the Miroslava tank varies between Z_M = (3.5 ÷ 7.5) m. The rehabilitation of the CUG pumping station aims at replacing the existing NDS pumps with new ones. In order to choose the correct pump variant we compared the functional catalogue characteristics of the pump with those of the pump eight pumps (Table 2), (*n* - rotor speed of the pump).

Table 1

The Operating Points of Experimental and Catalogue P1 and P2 Pumps

Parameter	$H_{R\,\max P1}$		$H_{R\,\min P1}$	
	experimental	catalogue	experimental	catalogue
Q_{pf}, [m^3/s]	0.105	0.131	0.129	0.145
H_{pf}, [m]	73	75.5	69	73
η_{pf}, [%]	67	81	69	81.5
Parameter	$H_{R\,\max P2}$		$H_{R\,\min P2}$	
	experimental	catalogue	experimental	catalogue
Q_{pf}, [m^3/s]	0.107	0.125	0.13	0.145
H_{pf}, [m]	73	76.9	70	71.3
η_{pf}, [%]	66	79	69	81.5

Table 2
Analysis of Possible Equipment Variants to Determine the Optimal Solution

Variant number	Pump	H [%]	n [rpm]	P [kW]	NPSH [m]	H [m]	Q [m³/s]
1	Wilo/IL250/460-160/4		1450 -	+			
2	Wilo/IL250/480-200/4		1450	+			
3	KSB/CPK/HPK300-500/504		1450				
4	Grundfos/NB,NK150-500/489/4		1490		+		
5	**Grundfos/NBG,NKG150-125-250/248/2**	+	**2980 +**	+	-	+	+
6	**Grundfos/NB,NK150-125-250/248**	+	**2980 +**	+	-	+	+
7	KSB/CPK,CPKN,HPK200-500/460	+	1450 -	+	+		
8	**KSB/CPK,CPKN,HPK200-500/480**	+	**1450 -**	+	+	+	+

According to the final analysis in Table 2, the following variants are recommended for the replacement of 8NDS pumps in the CUG Iași pumping station: 5) Grundfos/NBG, NKG 150-125-250/248/2; 6) Grundfos/NB, NK 150-125-250/248; 8) KSB/CPK, CPKN, HPK 200-500 / 480.

REFERENCES

Bagirov A.M., Barton A.F., Mala-Jetmarova H., Al Nuaimat A., Ahmed S.T., Sultanova N., Yearwood J., *An Algorithm for Minimization of Pumping Costs in Water Distribution Systems Using a Novel Approach to Pump Scheduling*, Mathematical and Computer Modelling, **57**, *3-4*, February 2013, 873-886.

Cherchi C., Badruzzaman M., Gordon M., Bunn S., Jacangelo J.G., *Investigation of Cost and Energy Optimization of Drinking Water Distribution Systems*, Environ. Sci. Technol., ACS Publication, 2015, 49 (22), 13724-13732, DOI: 10.1021/acs.est.5b03666.

Coelho B., Andrade-Campos A., *Efficiency Achievement in Water Supply Systems–A Review*, Renewable and Sustainable Energy Reviews, **30**, Ed. Elsevier, February 2014, 59-84.

Gama M.C., Popescu I., Jonoski A., Quan P., *Towards Increased Water and Energy Efficiencies in Water Distribution Systems*, Environmental Engineering & Management Journal (EEMJ), **14**, *6*, June 2015, 1271-1278.

Gong Y., Cheng J., Liu J., *Water Level Optimization of Water Transferring Channel in Multi-Stage Pumping Stations Based on Head-Water Level Successive Approximation Optimization Method*, Transactions of the Chinese Society of Agricultural Engineering, **30**, *22*, 2014, 120-129(10).

Goryashko A.P., Nemirovski A.S., *Robust Energy Cost Optimization of Water Distribution System with Uncertain Demand*, Automation and Remote Control, **75**, *10*, Ed. Springer Link, October 2014, 1754-1769.

Miron S.A., *Contributions to Hydraulic and Functional Optimization of Regional Water Supply Systems*, Doctoral Thesis, "Gheorghe Asachi" Technical University of Iaşi, 2013.

Price E., Ostfeld A., *Discrete Pump Scheduling and Leakage Control Using Linear Programming for Optimal Operation of Water Distribution Systems*, Journal of Hydraulic Engineering, **140**, *6*, Ed. ASCE Library, June 2014.

STUDIUL NECESITĂȚII REABILITĂRII STAȚIILOR DE POMPARE

(Rezumat)

Lucrarea urmăreşte realizarea unui studiu asupra reducerii preţului m^3 de apă potabilă furnizată consumatorilor industriali şi casnici, concomitent cu reducerea consumului de energie electrică. S-au pus în evidenţă elementele componente ale unui sistem hidraulic de transport, distribuţie, control pentru apă potabilă, precum şi interacţiunea şi influenţa reciprocă dintre ele; s-a studiat funcţionarea pompelor în reţea de transport - distribuţie. Metoda de optimizare a funcționării ansamblului stație de pompare – rețea de transport distribuție are două funcții obiectiv: costul total al insvestiției pentru reabilitare împreună cu costurile de exploatare (trebuie să fie minime) și randamentul total (trebuie să fie maxim). Se impune ca fiecare consumator activ în rețea să obțină pe perioada de 24 de ore condiții minime prevăzute de legislația în vigoare cu un preț minim al m^3 de apă potabilă. Metoda de optimizare propusă este aplicată în programele de calcul TriProgPomp for MATLAB, TrasareCarAn for MATLAB, CSHUP for MATLAB, DetDebitSA for MATLAB înscrise la Oficiul Român pentru Drepturi de Autor ORDA, seria S5001351 nr. 04518/30.11.2010; aceste programe de calcul au fost realizate de autoarea acestei lucrări. Metoda de studiu utilizată este aplicată la stația de pompare CUG Iași, România.