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THE WATER QUALITY'S IMPROVEMENT THROUGH THE OPTIMIZATION OF THE PARAMETERS FROM PUMPING STATION

BY

AURORA ALEXANDRESCU[*1] **and ADINA SIMONA MIRON**[2],

"Gheorghe Asachi" Technical University of Iasi,
[1]Department of Fluid Mechanics Fluid Machinery and Fluid Power Systems,
[2]Department of Land Improvement and Rural Evolving,

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Abstract. The paper aims is to determine the optimal parameters of the pumping station that to ensure proper water quality at a minimum cost price. The quality's improving of the drinking water in the water supply systems in large cities must be correlated with the minimum water pressure and flow rate for each consumer (industrial and domestic). The optimization method has two objective functions: unit specific energy consumption for pumping (must be minimum) and the overall efficiency of the hydraulic system (should be maximum). By applying this method seeks the lowest cost per cubic meter of drinking water supplied to consumers, under pressure and minimum flow. The optimization method is provided for water supply system Pacurari - Aurora - Breazu in Iasi city, Romania. This analysis takes into account the hourly flow variations throughout the hydraulic system considered (pumping stations Pacurari1, Pacurari 2, Breazu, Mijlociu, Aurora) and the relative volumes of water transferred between tanks Aurora Aurora 1 and 2 in the period June - July 2012.

Key words: compensation relative volume, overall efficiency, pumping aggregate, transport flow, unit specific energy consumption.

[*] Corresponding author; *email*: auralexis@yahoo.com

1. Introduction

The water treatment processes in the plants depends on the source water used: if used groundwater or surface. The quality of drinking water from the hydraulic systems must be monitored and meet the parameters set by international standards.

Based on the theory of decompose - coordination for large - scale systems, a systematic optimal operation model with multi - objective programming is developed for optimal allocation of water resources in Guangzhou City, South China. The methods of hierarchical analysis and step by step toleration obligation are used in the process of coordination through the sub-systems. Through the integrated regulation of reservoirs main rivers and the regional watersheds, estimated water amount for dry year is distributed optimally to 14 water resource units to meet water demand in the year 2020. Water shortage due to lack of runoff and insufficient water supply projects is analyzed. The scheme of water allocation within seven water resource districts is put forward to match the sustainable balance of water supply to water demand in Guangzhou City. The aim of setting up a matrix of water allocation rules is to allocate the weight of water user according to its priority under condition of water shortage. At the same time, after the completion of one round of water allocation, failure level of this scheme of water allocation is estimated by the matched degree of actual allocated water to water demand. It is the basis of determining whether or not the weights need to be adjusted for a new round of allocation. There are 4 levels in the matrix of water allocation rules, which are classified according to the failure levels of water supply. Horizontal vectors in the matrix represent the water allocation coefficient of water supply for agriculture, domesticity and industry at different failure levels, (Chen *et al.*, 2006).

A model for optimal operation of a complex water supply system for drinking water and with water quality, hydraulic and desalination treatment plants developed by Cohen and others has been applied to a realistic regional network, in which water quality is defined by salinity, magnesium and sulphur. The model considers the hydraulics of the network, including pump stations, boosters and control valves. The model considers network hydraulics by a sub-model, *Q-H*, which computes optimal set points for the hydraulic control devices. Solute transport in the model assumes conservative water quality parameters. Changes in water quality within the network are achieved by changing the removal ratio of reverse osmosis in desalination treatment plans and by control of mixing (dilution) at junction nodes. The decision variables in the model are the operation of treatment plants, pumps and control valves. The objective function of the model includes seven components: supply cost, treatment costs, boosters, pumping costs, agricultural yield losses, due to irrigation with poor water quality, and two artificial penalty costs. The model minimises the sum of the costs of water at sources, treatment, energy and loss of agricultural yield due to irrigation with low quality water. Three case studies are presented a network without treatment plants and water salinity as the only water quality parameter with treatment plants included and with the addition of magnesium and sulphur quality parameters. Control set points and cost of optimal operation for these three cases were computed. The model, however, was limited to conservative substances and steady-state conditions only, typical to rural communities and long-term operations. Extension of this model to unsteady conditions and reacting substances requires fundamental revision of the model and formulations. The results demonstrate the ability of the model to handle a regional water supply system having water quality problems, with optimal solutions being found in cases where there is a conflict between hydraulic and water quality requirements. The capability of the model to deal with realistic situations was demonstrated by solving examples for operating a regional network of the Central Arava System in southern Israel, with climate and environmental conditions similar to those prevailing in the south-west of the USA. (Cohen *et al*., 2009).

Two different numerical examples relating to networks of different topological complexity are discussed. In particular, it is highlighted that the two different ways of modelling demand lead to different nodal head values that are generally lower when demand is evenly distributed along the pipes. However, differences decrease when the piezometric surface is fairly flat over the network (i.e. low water velocities in the pipes). These results thus show that in high-density residential areas, where users are connected to the network *one right after the other*, the conventionally adopted schematisation that allocates demand to the nodes at either end of the pipe *without a proper correction of the head losses* may be overly simplified and potentially have a negative impact on the estimation of heads *H*. However, the negative effect is attenuated (becoming negligible) when the piezometric surface is fairly uniform, something that occurs when velocities inside the pipes are small. From these results, it is possible to derive several considerations concerning the problems of network calibration, design/rehabilitation and representation of leakage. (Fansini *et al*., 2010).

In addressing the problem of water distribution system design and/or rehabilitation, several recently published studies (Kapelan *et al*., 2005); (Tricarico *et al*., 2006); (Jayaram & Srinivasan, 2008) use network reliability as the reference parameter; reliability can be expressed, for example, as the probability that the head at all network nodes is higher than a given value. It is evident that the method of calculating nodal heads will influence the measurement of reliability and, based on what was shown previously, allocating demand to the nodes may lead to an excessively optimistic assessment of reliability (underestimation of head losses and hence overestimation of nodal heads).

(Gippel *et al.*, 2009) describe an approach to the integration of environmental flows recommendations into water resources planning and demonstrate its application to a case study in the Jiaojiang Basin, Taizhou, Zhejiang Province, and the People's Republic of China. In this approach, environmental flows recommendations were provided to the process as a preferred regime and also as one or more sub-optimal regimes. A risk assessment approach was used to derive the sub-optimal regimes from the preferred regime. The environmental flows rules were then incorporated into a wider water resources model which allowed testing of any number of development scenarios. The model-predicted daily time series' of river flows were passed through a sophisticated form of spells analysis to evaluate the degree of compliance with a specified environmental flows regime. This degree of compliance was balanced against the predicted security of supply to water users. This integrated approach allowed for a greater appreciation of environmental concerns by planners. It also provided an opportunity to the scientists who undertook the environmental flows assessment to contribute to the process of making rational trade-offs between risks to the environment and gains in security of supply.

The water resources allocation planning methodology adopted in this study involved the following seven steps, (Gippel *et al.*, 2009):

1. Identification of water resources availability and supply requirements.

2. Identification of environmental flow requirements.

3. Development of a water resources management model (IQQM: Integrated Quality and Quantity Model), capable of modelling the impacts of different operational and supply arrangements on the river flow and supply reliability.

4. Modelling of the current management and supply arrangements.

5. Development of different management scenarios, including scenarios that incorporate environmental flow requirements.

6. Analysis of the modelled results for each scenario, in terms of the impact on flows deemed important for the environment, and reliability of supply to water users (assuming fixed demand).

7. Identification of the way that a preferred management scenario could be converted into a water resources allocation plan.

Drought conditions in southwest Victoria, as in other regions of Australia and around the world, have caused the need to reduce water consumption to ensure security of supply into the future. To develop effective water-saving behaviour change strategies, an understanding of people's attitudes to the behaviour, including barriers stopping them from adopting the behaviour, is required. A conceptual model of the factors impacting on water use of these users, including drivers and barriers to water saving, is developed. The factors that appear to impact on water-use behaviour not previously identified included the source of water supply (groundwater versus surface water), previous experience with water shortages and trust in the water authority and government. Also, a difference in the drivers for water saving was found, with farmers wanting to be ‘water efficient’ to keep their business viable and productive, while hobby farmers and residential users were ‘saving water’ for more altruistic reasons. However, the conceptual model has to be tested to determine if it truly reflects factors influencing water-saving behaviour in rural and regional areas, (Graymore *et al*., 2010).

2. Method

The optimizing functional parameters of the factories pumping station water is achieved by using a computer program that belongs to the authors, CSHUP for MATLAB, protected to the Romanian Office for Copyright ORDA, certificate of registration in the National Register of Computer Programs S500 Series 1351 no. 04518/30.11.2010.

The compensation relative volumes were calculated needed throughout the complex system of water supply in the three periods of operation during the day (depending on the price of electricity): the vertex, gap and normal tariff zone. It was analyzed using vertex power by daily stop time. It aims to reduce the operating hours of pumping aggregate minimum for the period with maximum tariff and increase use the periods for gap and normal zone tariff. It is calculated the hour’s number year T_{year} and the hour’s number vertex T_v depending on stop time at vertex o_v using the computer program CSHUP for MATLAB with the following equations, (Fig. 1):

$$T_{year}(o_v) = 8760 - 365 * o_v; \quad T_v\left(o_v\right) = 1122 - 241 * o_v + 11.63 * o_v^2 , \tag{1}$$

where: T_{year} – hours year, [hours/year]; T_v – hours vertex, [hours/year]; o_v – stop time at vertex, [hours/day]. The relative volumes of compensation pumping v_{cr} are calculated for the pumping stations from Iasi city: Breazu, eq. (*2*); Mijlociu, eq. (*3*); Aurora 2, eq. (*4*); Pacurari 1 and Pacurari 2, eq. (*5*):

$$v_{cr\ Breazu}(o_v) = 6.40429 + 1.51495 * o_v + 0.1469 * o_v^2 , \tag{2}$$

$$v_{cr\ Mijlociu}(o_v) = 4.71895 + 1.50029 * o_v + 0.16214 * o_v^2 , \tag{3}$$

$$v_{cr\ Aurora2}(o_v) = 18.16305 + 1.30278 * o_v + 0.13294 * o_v^2 , \tag{4}$$

$$v_{cr\ P1,P2}(o_v) = 6.4964 - 0.44767 * o_v + 0.35274 * o_v^2, \left[\%\text{ from } Q_{day}\right], \tag{5}$$

The relative volume of compensation necessary pumping in the supply system of Iasi city has the equation (*6*):

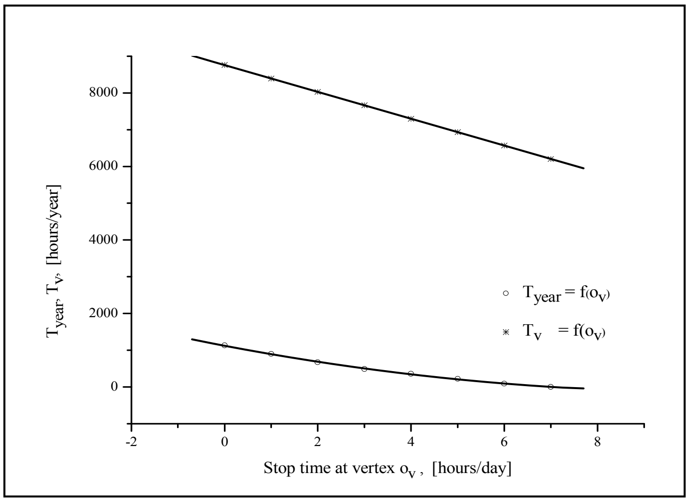

Fig. 1 − Number hours working at vertex curve heat SEN for June and July 2012.

$$v_{cr\ pumping}(o_v) = 4.1744 + 0.15866 * o_v + 0.01206 * o_v^2 \ , \left[\%\ \text{from}\ Q_{day}\right]. \tag{6}$$

4. Experimental Results

Fig 2 shows the relative volumes of compensation necessary v_{cr} [% from Q_{day}] depending on stop time at vertex o_v, [hours/day] for the following pumping stations: Breazu, Mijlociu, Aurora 2, Pacurari 1, Pacurari 2 and the relative volume of compensation necessary pumping in the supply system of Iasi city.

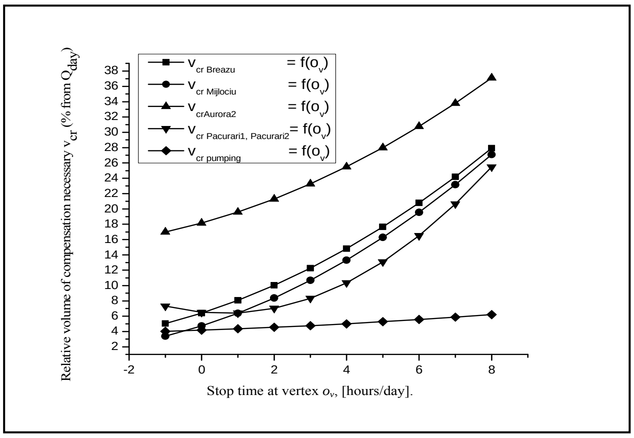

Fig. 2 − Relative volume of compensation necessary v_{cr} [% from Q_{day}], depending on stop time at vertex o_v, [hours/day] in pumping stations: Breazu, Mijlociu, Aurora 2, Pacurari 1, Pacurari 2 the relative volume of compensation necessary pumping in the supply system of Iasi city.

The relative volume of compensation necessary v_{cr} were assessed using data provided by the study of practical needs water in the water supply of the city Q_s of Iasi for 24 hours in different days of June and July 2012, (Fig. 3). We obtained an average for the consumptions.

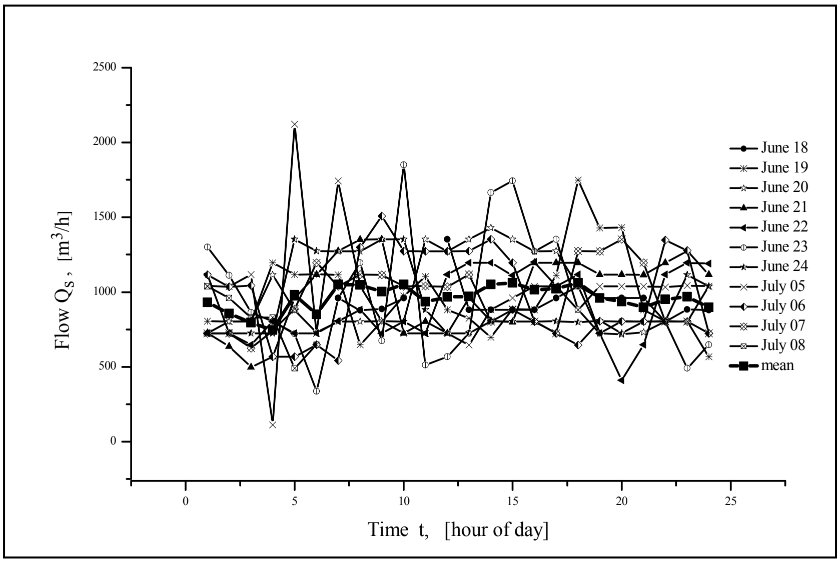

Fig. 3 – Flow variation Q_s in the supply system with water pumping stations Pacurari 1 – Aurora for June and July 2012.

Computer program CSHUP for MATLAB correlates volumes of water supplied from Iasi pumping stations required for the each consumer consumption within 24 hours, using a specific consumption of electricity for pumping unit minimum and a maximum overall efficiency of the hydraulic system. It is determined the following parameters: $Q_{rel\ ref}$ - relative water flow discharged; $Q_{rel\ tranf}$- relative flow of water transferred between tanks Aurora 2 and Aurora 1; $W_{dif\ ref}$ - the difference in water volume discharged; $W_{dif\ supply\ cont}$ - the difference in water volume for continues supply; $W_{dif\ supply\ 17\ hours}$ - difference in volume of water through supply for 17 hours, (*fig. 4*).

5. Conclusions

The computer program CSHUP for MATL does reduce the number of operating hours for the pumping units to a minimum during periods of maximum tariff for the electricity and increasing use periods for the pumping units in empty areas and normal charges for the electricity. The flows provided by pumping stations and relative volumes stored in reservoirs are correlated with pressure and ensure a minimum flow allowed for each industrial and domestic consumers.

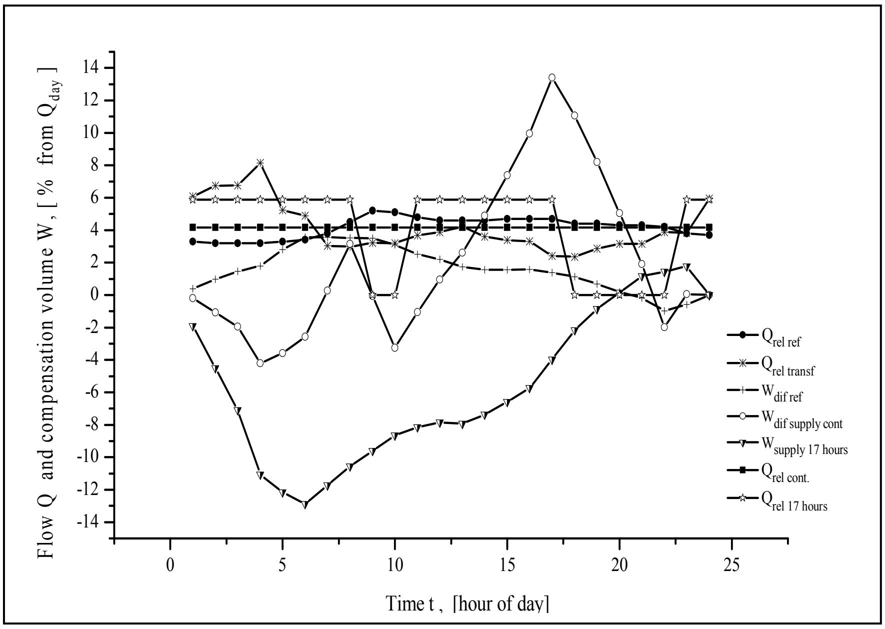

Fig. 4 − Flow and variation of the compensation volume in the transfer from Aurora 2 to Aurora 1, for June and July 2012.

It can diminish with 10 - 15% the price of cubic meters of water supplied by correlating the functional parameters of the pumping station - transport distribution network - consumers assembly with the reduce operating periods during periods of vertex load at maximum tariff.

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IMBUNĂTĂȚIREA CALITĂȚII APEI PRIN OPTIMIZAREA PARAMETRILOR DIN STAȚIILE DE POMPARE

(Rezumat)

Lucrarea îşi propune sa stabilească parametrii optimi ai staţiei de pompare care să asigure o calitate corectă a apei potabile la un preţ de cost minim. Îmbunătăţirea calităţii apei potabile din sistemele de alimentari cu apa din oraşele mari trebuie corelată cu asigurarea presiunii şi a debitului minime pentru fiecare consumator, (industrial şi casnic). Metoda de optimizare are două funcţii obiectiv: consumul specific unitar de energie pentru pompare (trebuie să fie minim) şi randamentul total al sistemului hidraulic (trebuie să fie maxim). Prin aplicarea acestei metode se urmăreşte obţinerea celui mai mic preţ de cost pentru metrul cub de apă potabilă furnizată consumatorilor, în condiţii de presiune şi debit minime admise. Metoda de optimizare este aplicată în cazul sistemului de alimentare cu apă Păcurari – Aurora – Breazu din judeţul Iaşi, Romania. Această analiză ţine seama de variaţiile debitului orar în întreg sistemul hidraulic considerat din orasul Iasi şi de volumele relative de apă transferate între rezervoarele Aurora 1 şi Aurora 2 în perioada iunie – iulie 2012.