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DEVELOPMENT OF THE AUTOMATIC CONTROL SYSTEM OF PUMPING STATION FOR URBAN WATER SUPPLY

Evgeniy Pistun[1], Natalia Yakymchuk[2]
[1]Lviv Polytechnic National University, Lviv, Ukraine, [2] Lutsk National Technical University, Lutsk, Ukraine

Abstract. *The analysis of the automatic control of water intake area of the pumping station, which is based on a controller with fuzzy logic and systematization using seasonally and hourly water consumption by using wavelet transforms.*

Keywords: water resources, wavelet transforms, fuzzy control, adaptive systems

ROZWÓJ AUTOMATYCZNYCH SYSTEMÓW STEROWANIA STACJĄ POMP ZASILAJĄCĄ MIASTO W WODĘ

Abstract. *Analiza automatycznej kontroli poboru wody pompowni, opartej jest na regulatorze rozmytym i systematyzacji na podstawie sezonowego i godzinowego zużycia wody z wykorzystaniem transformaty falkowej.*

Keywords: zasoby wodne, transformata falkowa, sterowanie rozmyte, systemy adaptacyjne

Introduction

The problem of water quality is important for many settlements of Ukraine. The use of outdated equipment pumping stations, lack of effective monitoring and control of pump units leads to overspending of electricity backed excessively high pressure in water supply networks, which increases the risk of accidents. The basic amount of electricity consumed by the pumping station is spent on power pumping units. The water supply is constantly changing, then the pressure that develops pump unit must vary sufficiently flexible to reduce overspending electricity and unproductive water losses.

1. The purpose of the article

The aim of this work is to develop a method for improving the energy performance of water by using an adaptive automatic control system of fuzzy logic.

2. Research of urban water supply using wavelet transform

For one of the areas of intake pumping station in Rivne (intake area "New Yard") a systematization in Excel measured using a flow sensor "Vzlet MR" values of the hourly cost of water supplied to the water supply network of the city in the summer and autumn- winter period (during rendering of heat).

On the basis of this information, we received the control signal, as a set of successive approximations. To this end, wavelet transform is used which is usually applied for signal processing, showing the evolution over time of their main characteristics - the average, variance, periods, amplitudes and phases of harmonic components [1]. Such as these signals is hourly change of the water flow in the water supply network of the city.

On the basis of experimental data on the change in water consumption by their wavelet transform, whereby the received signal (noise isolation), which enables further use of this signal as an input task of the regulator, which will regulate the pump units. To do this, the software uses wavelet analysis of data in the form of expansion pack Complex Wavelet Toolbox software Matlab. It includes tools for learning, creating and using wavelets and wavelet transforms as in command mode, and with the help of special tools with graphic user interface(GUI).

On the basis of received experimental data of hourly water consumption in summer and autumn- winter (during the heating season) periods they were systemized. Later we used the method of Wavelet 1 -D to schedule a one-dimensional signal. We obtained the trends of water consumption hourly change separately for weekends and weekdays. Comparing these trends, it is concluded that the hourly output trends and days are quite similar, so there is no need to continue their consideration separately. Similarly we received hourly water consumption trends for the summer (Fig. 1) and autumn-winter (Fig. 2) periods (during the heating season).

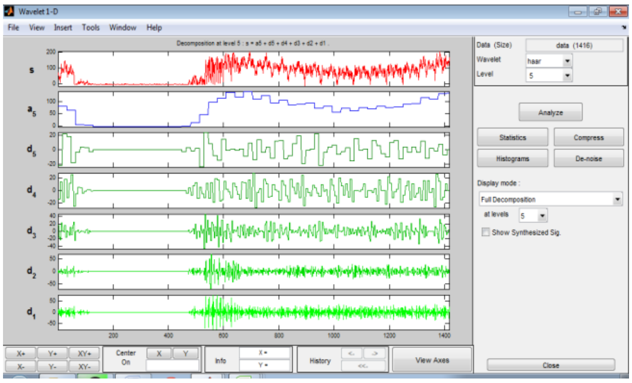

Fig. 1. Hourly trend of water consumption during summer (09.06.2012-06.08.2012)

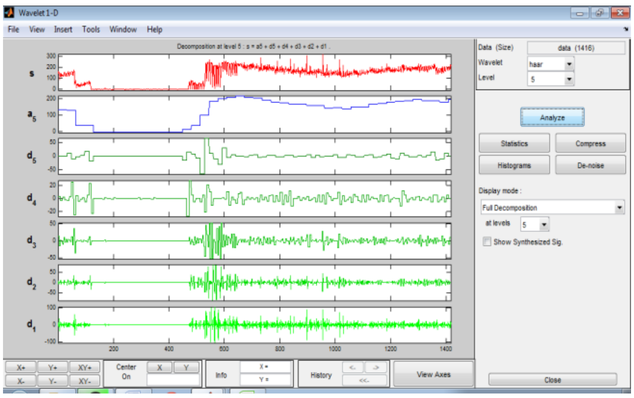

Fig. 2. Hourly trend of water consumption during autumn-winter (30.12.2012-19.01.2013)

Comparing the results for the two periods we concluded that the trend of the autumn- winter period has larger values of water consumption than summer. This difference - it is more in the water that goes into heating.

3. Design of fuzzy controller

These approximations (useful signal) can be further used in developing control system of pump unit based on the theory of fuzzy control systems [3]. Application of fuzzy inference approach is justified and sometimes only possible when it is necessary to describe the behavior of a complex system and get a chance to determine the values of some parameters of the system based on the values of other parameters or environmental parameters. To describe the behavior of the system using two basic concepts of fuzzy logic: a linguistic variable P and the term linguistic variable T. Chance of fuzzy logic corresponds to one of the parameters that characterize the system, such as flow rate, pressure and so on. The measured value of the parameter will appear "clear" value of the variable. The whole set of distinct values forming the domain of the linguistic variable. Term is a variable it "fuzzy" value and is defined phrase that describes one characteristic state system parameters.

When using the method based on fuzzy definition of the management process, there is the possibility of forming an optimal set of commands on the criterion of least energy consumption and delivering the required flow of water to consumers. Fuzzy controller provides higher quality scores transients in comparison with classical regulators [2]. To the great advantages of fuzzy control should include its focus on digital implementation. Systems of this kind have enough great flexibility and good quality of the transition process - the minimum time with minimum overshoot regulation.

Productivity, which should produce a pumping station, is determined by the previous value of the flow of water received by us by wavelet transform with the specification of water now, which is measured by a flow meter at the outlet of the pumping station.

At the input of the fuzzy controller have three variables, including the "difference of water consumption", which takes the value of "very low", "low", "average", "high" and "very high". Naturally, the larger the difference of water consumption at the moment, the greater must be the performance. The second linguistic variable defined "rate of change of consumption" in the network, which was also given to the linguistic meaning of "very low", "low", "average", "high" and "very high". The higher rate of change in consumption requires higher pumping station performance. When the water flow created by the pump unit is approaching to the corresponding rate of change of consumption expenditures in the network will decrease and the productivity of pumping station will reduce. The output variable is a unified signal, which is fed to the frequency converter. He was assigned to the following terms: "very low", "low", "moderately low", "below average," "average," "above average," "moderately high", "high" and "very high" (Table 1).

Table 1. The relationship between the variables of fuzzy control system

Rate of change of consumption	Difference of water consumption				
	Very low	Low	Average	High	Very high
Very low	Very low	Low	Moderately low	Below average	Average
Low	Low	Moderately low	Below average	Average	Above average
Average	Moderately low	Below average	Average	Above average	Moderately high
High	Below average	Average	Above average	Moderately high	High
Very high	Average	Above average	Moderately high	High	Very High

In the event of a sharp pressure decrease in the city water supply network, while ensuring its flow rates calculated according to consumption rates, emerging signal of the likelihood of an emergency, i.e. rupture of pipelines.

Done fuzzy controller design using fuzzy module in Matlab environment using Mamdani type designed framework of rules, variables and terms for the renamed input variables giving them names zmina-vytraty (consumption change), shvydkist-zminy (the consumtion change rate) and tysk (pressure), and output variables describing their sygnal (signal) and sygnal-avarii (alarm signal) (Fig. 3)

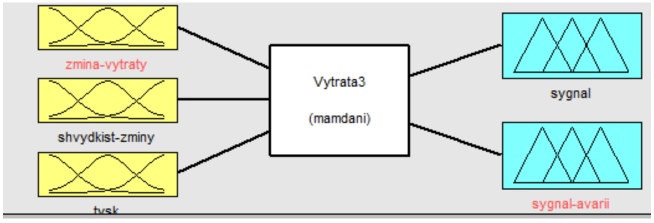

Fig. 3. The designed model of fuzzy controller

Using the editor of membership functions the variation range was set for variables zmina-vytraty and shvydkist-zminy using five terms with the triangular shape and the variable tysk was introduced with three terms, after which they were named. A membership function for the output variables was given. To assess the linguistic variable signal using 9 terms of triangular membership functions and to sygnal-avarii – d 3 terms. Using the editor of knowledge base RuleEditor the rules were formulated.

Figure 4 shows the visualization window of fuzzy inference. In the "Input" specified values of input variables for the logical conclusion.

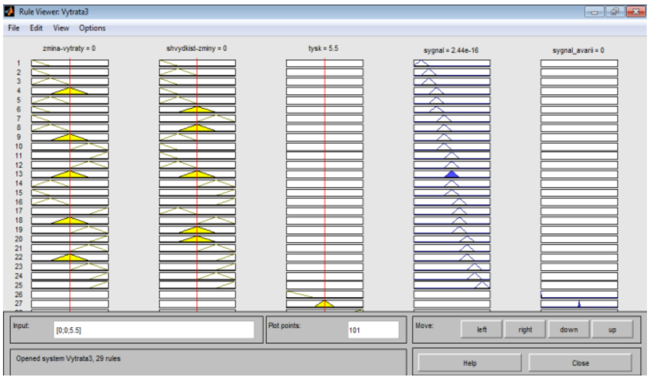

Fig. 4. Visualization of fuzzy logic conclusion in RuleViewer

4. Modeling of control system of pumping station

Based on the designed fuzzy controller had been carried modeling of control system of pumping station. A model of such a system is shown in Fig. 5. The input parameters of the control system are the current flow, the pressure in the network, and the signal of the chosen season of the year (summer or winter). Output parameters: control signal applied to the frequency converter, alarm pressure on potential emergency situations and previous consumption, obtained by wavelet transform, to compare with the current.

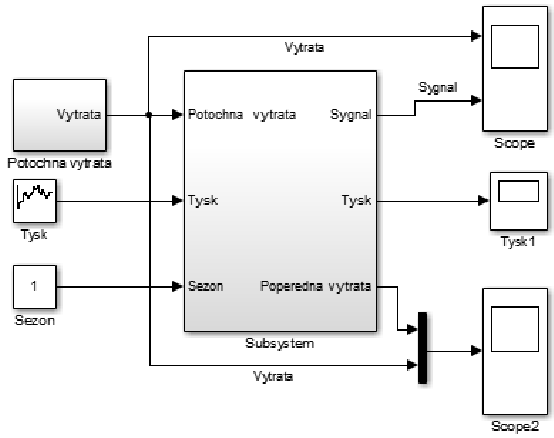

Fig. 5. The model of the control system

A subsystem named «Potochna vytrata» was created. Current consumption is specified by blocks Ramp, simulating time and 1 - D Lookup Table, where each value of time corresponding to a specific value of water consumption (Fig. 6).

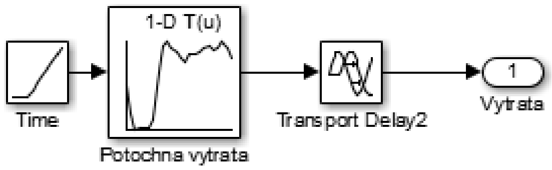

Fig. 6. Subsystem «Potochna vytrata»

Proceed directly to consideration of the control system (Fig. 7).

Subsystem «Vybir sezonu» (Fig. 8) is as follows: Depending on the selected signal Sezon corresponding value of water consumption, which was obtained by wavelet transformation (1 - for winter, 2 - for the summer). Output parameters are preliminary water flow, and control signal derived from this flow (Poperedniy sygnal).

Subsystem «Fuzzy regulator» (Fig. 9), simulating fuzzy controller. The input parameters of the controller are: changing consumption supplied from the adder, and is the difference between current flow and the one that was in an earlier time, the rate of change of the flow, which is determined by differentiating the current pressure and flow in the network. Accordingly to the base of the rules described above, receiving the numerical value of signal change in either direction (± 16mA). Another parameter is the output signal of the possibility of an emergency, if the pressure is low (<4 at), the output we get (-1), in the normal range (4 ... 7 at) – 0, high (> 7 at) - (+1). There are checks in the event of a reduction in pressure below that required for normal water farthest point. In the event that less pressure is required, the frequency converter in real time mode increased by 0.5 mA signal that is intended to increase the pressure at the network.

Subsystem «Pochatkove» publishes preliminary control signal, which is based on current water flow and moves one step (Fig. 10).

Subsystem «Zatrymka peremyk» is designed to eliminate the decline of the output signal to 0 at the initial time (Fig. 11).

Consider the subsystem of determine the final output. Based on pre-defined trend of water consumption, obtained by wavelet transforms, for half an hour to how need to provide the necessary flow seems appropriate control signal. At the same time this control signal in the specific moment of time will be clarified based on current flow (Figure 12).

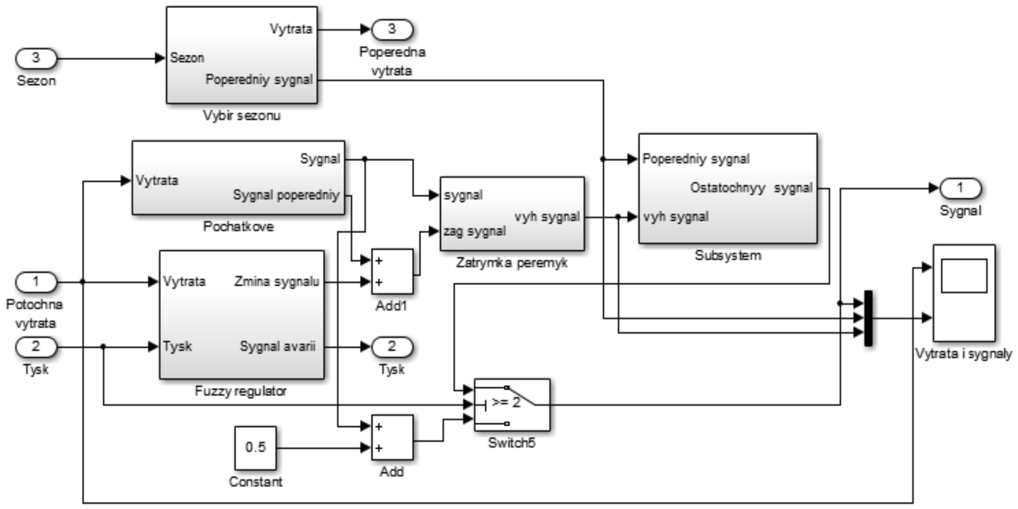

Fig. 7. Main control system

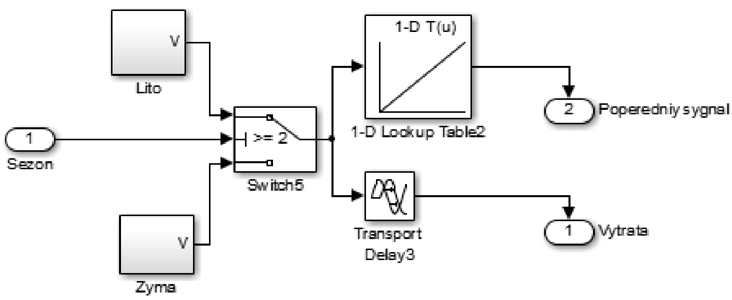

Fig. 8. Subsystem for choice of the season

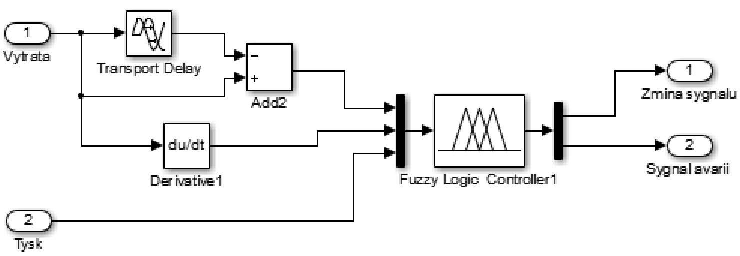

Fig. 9. Subsystem «Fuzzy regulator»

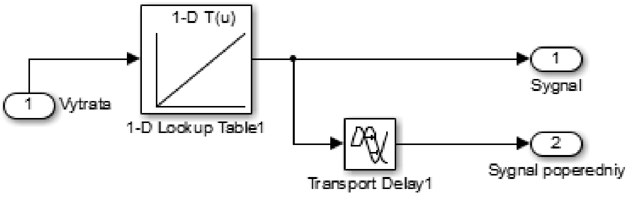

Fig. 10. Subsystem «Pochatkove»

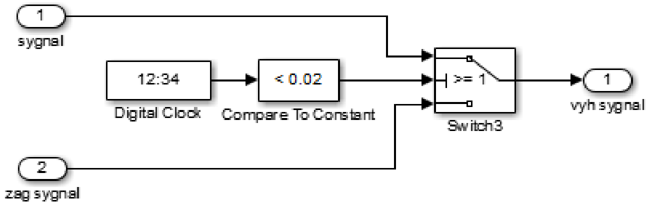

Fig. 11. Subsystem «Zatrymka peremyk»

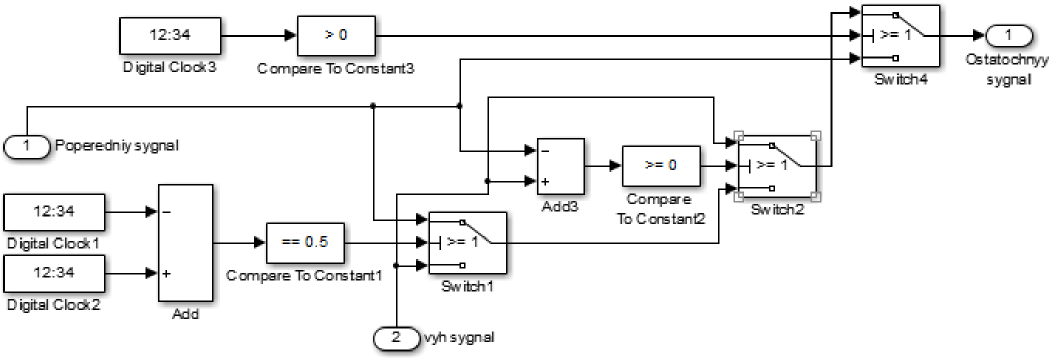

Fig. 12. Subsystem of definition resulting signal

5. Results

After simulation we received following graphics (Fig. 13).

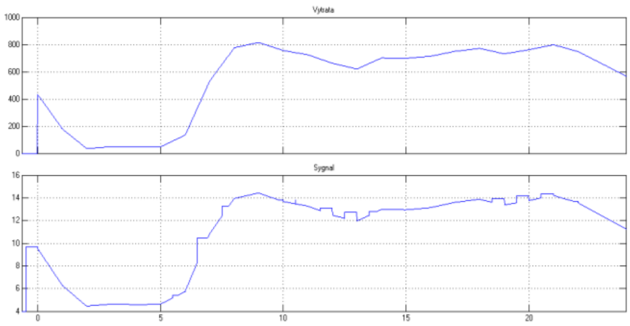

Fig. 13. Graphs of current water flow and the final control signal

Analysis of simulation of automatic control system with fuzzy controller confirms the high quality of the adjustment process of daily water supply to customers according to their requests.

6. Conclusions

Based on the data of hourly water consumption we systematized it and made wavelet transforms of this signal. Further we can implement fuzzy control system. It will allow avoid accidents on the pumping station and the excessive consumption electric energy and also it will lead to increase efficiency of processes, the reliability of the water supply and rational use of material and energy resources.

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Prof. D.Sc. (Technical) Evgeniy Pistun
e-mail: acit@polynet.lviv.ua

Head of Automation, thermal and chemical processes Department, Lviv Polytechnic National University. The most significant application development performed under the supervision of Professor Pistun are: technological and test equipment for manufacturing processes of optical fibers, semiconductor devices, integrated circuits and other microelectronic products; set of devices to measure consumption and quantities of gas and liquid by method of differential pressure; composers of gas mixtures; devices for measuring conductivity of the material; the system of automatic control and process optimization of grinding hard materials in the ball drum mill.Author of over 150 scientific papers and patents, including in U.S., UK, Germany, Sweden, Poland and Japan, most of which are implemented in production.

M.Sc. Natalia Yakymchuk
e-mail: selepyna@ukr.net

Research engineer of computer systems and automation, postgraduate student, assistant of the Department of physics and electrical engineering, Lutsk National Technical University.
The main scientific direction – automation of water supply processes, construction of data collection, information-processing and industrial automation systems; research, design and modeling of automation systems for the water pumping stations.

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