Development of Neural Network Control and Software for Dispatching Water Distribution for Irrigation

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Abstract

The software product is proposed for performing the dispatching task of distributing water resources of the hydromeliorative irrigation system.

This software product allows you to monitor and calculate the costs and volumes of water necessary for the needs of water users, as well as the water balance on the irrigation system.

Using the accounting program ACDU_2019, the manager of main networks enters indicators: water levels and the height of lifting gates at each structure. During data processing, instantaneous, average daily consumption, and volumes of water per day and per year are determined. For convenience and time-saving, when the required flow is introduced through the hydraulic structure, the dispatcher receives the opening height of the shutters at the corresponding horizons. The results of the development of an intelligent irrigation complex control system taking into account actual moisture reserves are presented, which allows both optimizing irrigation rates depending on the level of actual moisture reserves in field areas, and ensuring optimal operation of sprinkler equipment in each irrigation area through the introduction of neurocontrollers into the control system. The proposed architecture of an intelligent irrigation complex control system allows both its integration into the structure of digital decision support platforms and its use in the development of new models of sprinkler machines.

Keywords [1]

Product, network software, method, water distribution, hydrotechnical structure, reclaimed land, irrigation.

1. Introduction

Long-term intensive agricultural use of irrigated areas lands led to an increase in the diversity of agro-ecological conditions, changes directions of soil formation and ecological and reclamation state of lands, and the economic problems of recent years have led to an unstable deficit resource provision in irrigated agriculture and deterioration of technical state of irrigation systems [1-7]. However, the shortcomings in organization of water use during irrigation and often lack of operational irrigation planning led to negative consequences (development of flooding and salinization of agricultural land) [8-11]. Therefore, the water supplied at irrigation, instead of being useful, became, in a few cases, ecologically harmful. It due to the fact that the water balance of the territories is changed without highly qualified management of this process, scientific ones were not used recommendations In the new conditions of management, land reclamation is an important direction of development is the

development of economic, organizational, and technological foundations that justify as economic relations in the field of water management and reclamation, and rely on progressive technologies (irrigation regimes, water use technologies) [11-14].

The modern trend of sustainable development in irrigated agriculture, particularly in regulated water use, must be based on three key positions: computerization – environmentalization – resource conservation [12, 15-19].

Computerization is a transition to new technologies of water use, because how it is known that modern civilized society is moving to a higher stage of its development - an information society with the use of high-precision irrigation technologies [12, 14, 20-23]. Modeling is a method based on using the model as a means of researching natural phenomena and processes [8, 24-28].

Models are systems that replace the object of knowledge and serve as a source of information about it. Computer models are analogs whose similarity to the original is significant, and the discrepancy is insignificant [9, 12, 14, 29-33].

Resource conservation is considering the indisputable fact that it is significant the number of natural resources, especially non-replenishable ones, is on the limit of exhaustion or disappearance, and such a very important one - like fresh water and water for irrigation, although it refers to the replenishment resources, is everywhere pollution and clogging within unacceptable limits of flooding in irrigated areas.

2. Methods and Techniques

The main task of the dispatcher service of the irrigation systems is the maintenance of water levels in canal compartments and the provision of normal water level pumping stations.

After each dispatch hour, monitoring is carried out, and calculation of costs and volumes of water necessary for the needs of water users, and also the water balance on the irrigation system.

Using the calculation program ACDU_2019 [12, 14, 34-37] dispatcher of main water networks enters indicators: water level and elevation shutters on each building. During data processing, instantaneous, average daily consumption and volume of water per day and per year.

For convenience and time-saving when entering the required cost through the gauges at hydraulic structures the dispatcher receives the opening height of the shutters at the corresponding horizons.

System Requirements for Installing the Program

Program version ACDU_2019_D_R15a0912 requires up to 15 MB of disk space memory. The program is delivered on a compact disc (CD ROM) or USB flash drive storage device. The following minimum requirements are required for a successful installation:

• a computer with a microprocessor no lower than Pentium IV, Athlon MP, and higher;

• compact disc reader (CD_ROM or DVD drive), mouse, 8-bit graphics adapter, and monitor support of at least 256 colors;

• Windows XP / 7/8/10 operating system;

• RAM with a capacity of 512 MB and above);

• up to 2200 MB of disk space for installation and libraries.

Installation of the program

The MCR library must be installed before running the program if it was not installed in the operating system for the previous version ASDU.

To install the library, it is enough to install a CD_ROM (USB) with the file MCRInstaller.exe and run it as usual. After extracting the files further operations are carried out according to the instructions of the installer windows.

Installation takes some time - about half an hour for older PCs. After completing the installation of the libraries, a reboot must be performed computer.

The installation program itself does not need to be installed. It must be transferred from CD_ROM (USB) to the hard drive and create a shortcut on the manager's desktop for running the file ACDU_2019_D_R15a0912.exe.

Description of the intelligent irrigation complex control system

The next task of this article is to design an intelligent control system for the irrigation complex, which is based on two components:

1) Differentiation of irrigation regimes, taking into account the differentiated needs of irrigated crops for water in different phases of growth and development and the spatial variability of the natural conditions of a specific irrigated agricultural landscape.

2) Optimization of control of sprinkler machines, allowing to ensure the accuracy of achieving optimal irrigation rates depending on the level of actual moisture reserves of field areas.

The first component is a digital technology, implemented in the high-level programming language Python, optimizing the moisture parameters of the calculated soil layer based on databases and knowledge of determining the optimal parameters of moistening the calculated soil layer for the main irrigated crops. The second component is neurocontrollers integrated into the sprinkler control system, ensuring the accuracy of optimal irrigation rates in each area.

3. Results and Discussion

Due to the fact that the main parameters that determine the value of the irrigation norm are the thickness of the moistened soil layer and its pre-irrigation moisture, resulting from the biological characteristics of the cultivated crop in various phases of growth and development, as well as bulk density and moisture content at the lowest moisture capacity of the moistened soil horizons, significantly different for different soil varieties and granulometric compositions, their incorrect choice can lead to both drying out of the root layer, correspondingly to a loss of productivity of irrigated crops, and to excessive water supply, leading to unproductive losses of irrigation water, its filtration into groundwater, reaching in some cases irrigation systems 15-20% of the total water supply for irrigation. Each sprinkler as part of the irrigation complex is located on a specific area that has certain geo-coordinates, which determines the presence of spatial variability of soil, geomorphological, hydrogeological conditions (Figure 1, 2). In addition, there may be spatiotemporal variability in both the crop and its phase of growth and development.

Figure 1. Photo of the irrigation complex

As is known, irrigation rates (m, m³/ha) are determined based on the basic water-physical properties of irrigated soils and the characteristics of water consumption by plants, according to the formula

$$m = 100hr(W_{mc} - W_{lp}),$$

where h (m) is the value and r (t/m^3) is the density of the calculated soil layer; W_{nc} and W_{lp} – humidity corresponding to the lowest moisture capacity of the soil and the lower pre-irrigation threshold of soil moisture, % of the mass of absolutely dry soil.
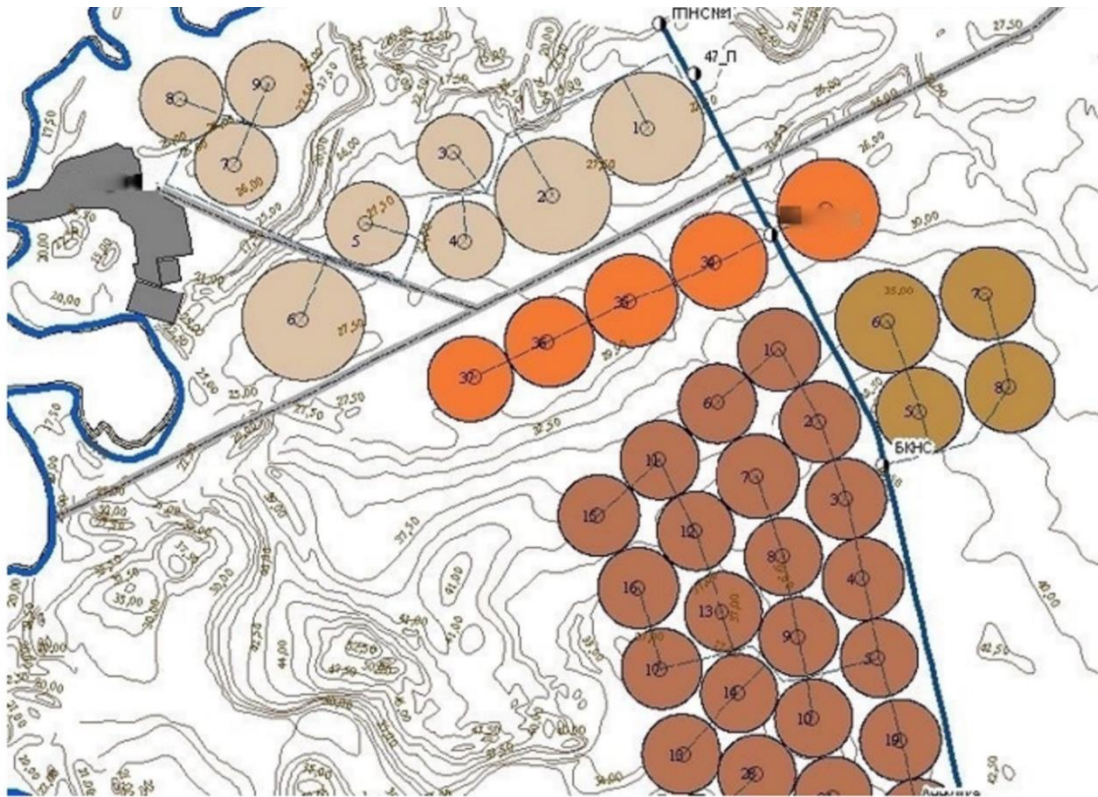

Figure 2. Digital map of the irrigation complex

For such irrigated crops as soybeans, corn, winter wheat, sorghum, alfalfa, sugar beets, potatoes, goat's rue, millet, brome, an analysis of the conditions of irrigated agriculture in the Saratov region was carried out. Based on this, differentiation of irrigation regimes was established, taking into account the pre-irrigation moisture threshold and the depth of the wetted layer. To optimize the moisture parameters based on the developed databases and knowledge of determining the optimal moisture parameters of the calculated layer of soil differences for the main irrigated crops, a digital technology based on the Python programming language has been developed.

The result of her work is to find the optimal parameter of the irrigation rate m^*_k for the plot numbered "k" of irrigation, taking into account the type of soil, its granulometric composition and information about the crop, its phase of growth and development. The second component of the intelligent system is the control of the sprinkler at the irrigation site. Based on field research data on an experimental basis, an analysis of the movement tracks and actual speeds of the sprinkler was carried out in real time in relation to geolocation (Figure 3,4). The analysis showed that the actual values differ from the established ones, and the deviation rate is 8-13% depending on the spatial and temporal location. In this case, irrigation norms deviate by 7.4-11% from the required ones.

It is known [4] that the irrigation rate is:

$$m = \frac{600Q}{2\pi RV_c}$$

where V_c is the average speed of the trolley, m/min, Q is the water consumption of the sprinkler and R is the irrigation radius.

So it is a function of speed:

$$m = f(V).$$

Figure 3. Tracks of movement of a circular sprinkler
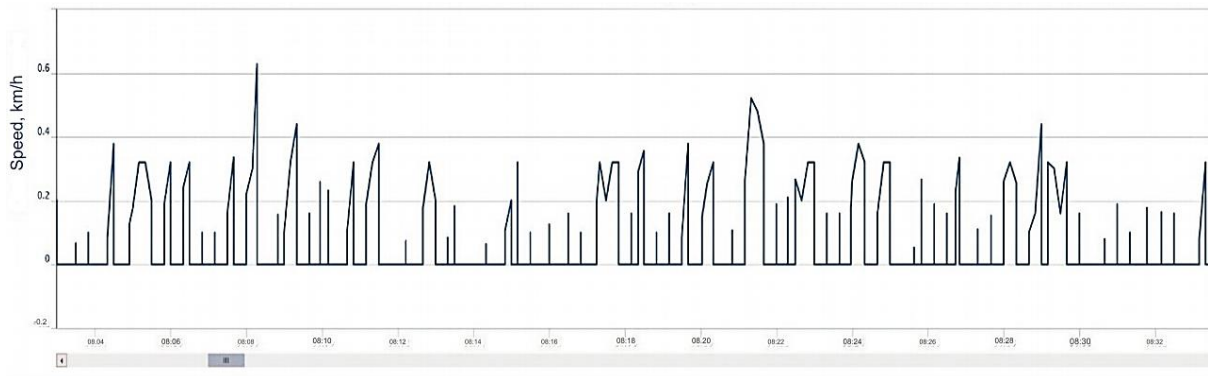

Figure 4. Speed graphs for center pivot sprinklers

Therefore, achieving the optimal value of irrigation norm m^*_k for a certain irrigation area is possible only through the introduction of effective mechanisms for controlling the speed of sprinkler equipment. Such mechanisms include neurocontrollers for the speed of a sprinkler. Neurocontrol of technical objects belongs to the actively developing modern direction of intellectualization of technical systems. Multilayer neural networks have numerous applications in the control of technical objects and systems. In this regard, they can be used to control sprinklers as adaptive controllers. In this case, a control action with optimal characteristics is generated during the training of the neural network, and it is this that is supplied to the system input. In our case, the optimal value of speed V^*_k is found from the equation:

$$m^*_k = f(V).$$

The introduction of neurocontrol methods into control systems for irrigation machines makes it possible to improve the quality of their functioning. A neurocontroller is synthesized directly in the computing module of the system, which for a given moment in time, with known values of input disturbances, finds the value of the control action and its subsequent implementation in the control module. The task of controlling the neural network is to bring the actual speed value as close as possible to the required value V^*_k. To synthesize a neurocontroller, you can use various software products. We used an algorithm implemented in the Matlab environment (Neural Network Toolbox package). The neural network diagram and neuromodeling results are shown in Figure 5.

After training, the regulator is used in the control loop, reducing deviations to 1-3%.

Software for dispatching water distribution for irrigation

Based on the tasks performed by water outlets, they work continuously or periodically. Water outlets designed for these purposes work without interruption at all water levels in the main channel. Therefore, in the design of such water outlets, it is useful to have two or more independently working

threads of pipelines. If repair work is necessary, one of the threads is disconnected, and the rest continue to operate, ensuring a continuous supply of water to the consumer.
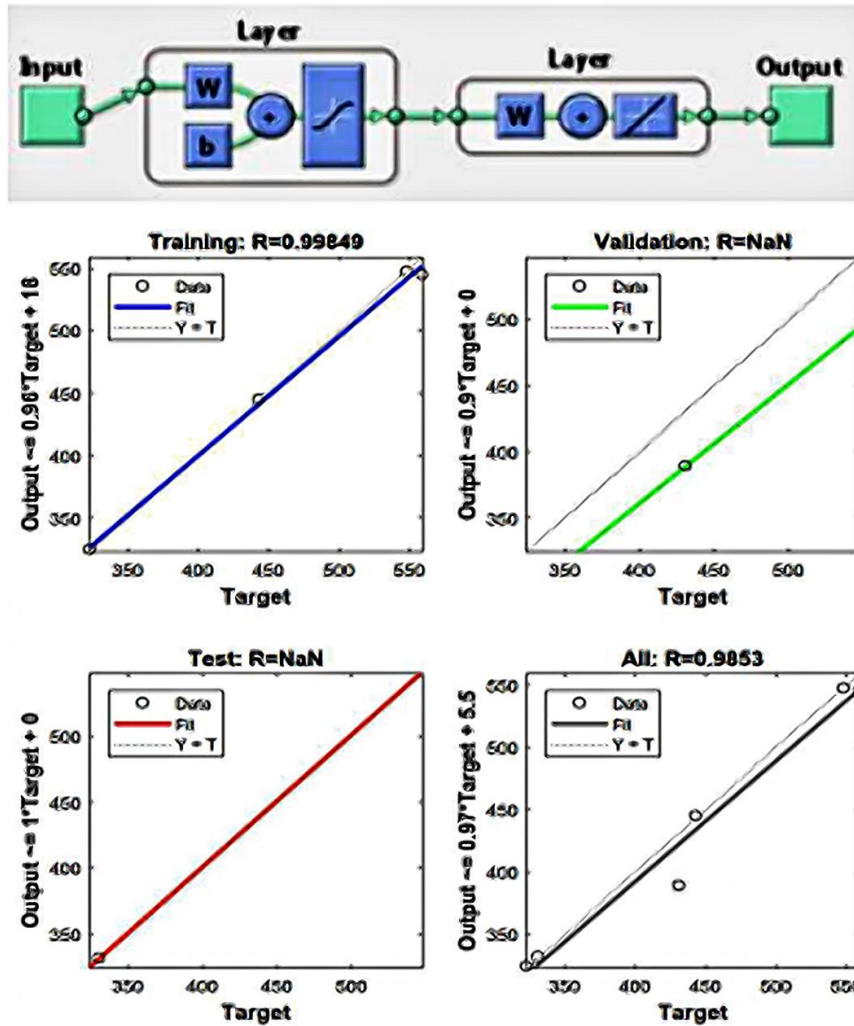

Figure 5. Diagram of a neural network (top) and results of neuromodeling in Matlab (bottom)

Continuously working water outlets during periods of high water levels in the main channel are under high pressure, for extinguishing which powerful extinguishing devices are required. In addition, it is necessary to take into account the appearance of cavitation and accompanying cavitation erosion.

Hydraulic calculations of water discharges with a flooded outlet are performed according to the formula [11-14, 25-29]:

$$Q_p = \mu_T \omega \sqrt{2gz}, \tag{1}$$

where μ_T - the flow coefficient of the pipeline:

$$\mu_T = \frac{1}{\sum \xi}, \tag{2}$$

z - the difference in levels between the lower and upper beefs:

$$z = H_U - H_L, \tag{3}$$

ω - cross-sectional area of the pipe:

$$\omega = \frac{\pi d^2}{4}, \tag{4}$$

$\sum \xi$ - the sum of resistance coefficients:

$$\sum \xi = \xi_{ent} + \xi_{oth} + \xi_{ex} + \xi_p, \tag{5}$$

When determining the flow rate of a pressure water outlet, it is necessary to take into account the coefficients of frictional head losses and local head losses. Local pressure losses in deep pressure

spillways should include the following: at the entrance, in the grooves of the shutters, at the bends of the tract, in the confusion and diffusers, when flowing around intermediate bulls and other supports. In addition, the coefficients of head losses at the exit from the water outlet in the event of flooding of the outlet section from the side of the lower side, and the coefficients of head losses of partially open shutters and deflectors should be taken into account.

The ACDU_2019_D_R15a0912 program is designed for round-the-clock, year-round, multi-year continuous work. After running ACDU_2019_D_R15a0912, the main screen appears in the system window shown in Figure 1. It has the usual controls, concealment, and closure. The purpose of windows and menus is intuitively clear from the inscriptions above them Elements The absence of information in the windows "Date - Time" and "last polled time," says that the program is in in startup state.

Figure 6. ACDU system window after startup

How its work?

1. *Open the "Dispatcher:" menu and select the last name of the dispatcher on duty. This operation can be performed both with a "mouse" type manipulator and with the help of the "Tab" keyboard keys and the "↑" "↓" arrows (Figure 2).*
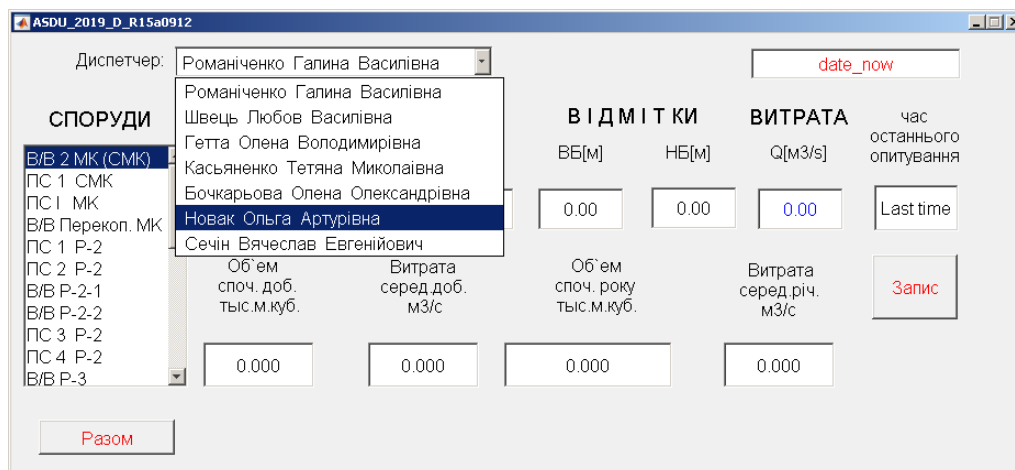

Figure 7. ACDU system window during selecting the dispatcher

Figure 3 shows the view after selecting the dispatcher on duty. The "Date - Time" field is filled with system values. The absence of information in the "time of the last survey" field indicates that the program is in a running state.

2. *Select a building in the "Hydrotechnical structure" list*

When you first select a hydrotechnical structure, the "_ASDU_2019_Arhiv" folder is created to store archival information. The archive folder is created on the C: or D: drive, depending on the

version of ASDU. In the archive folder, archive text files are created for each hydrotechnical structure. The name of the files consists of the name of the hydrotechnical structure, and the date and system time of its creation.
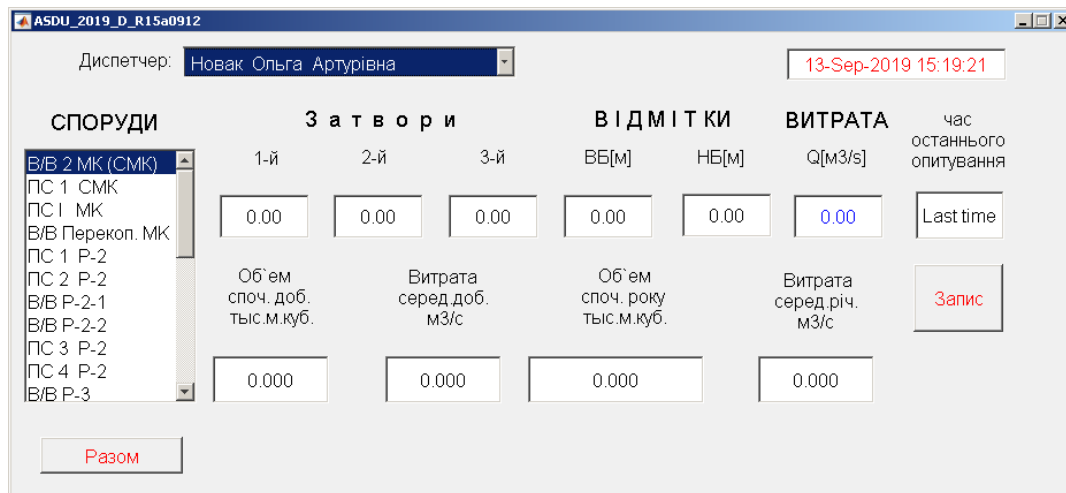

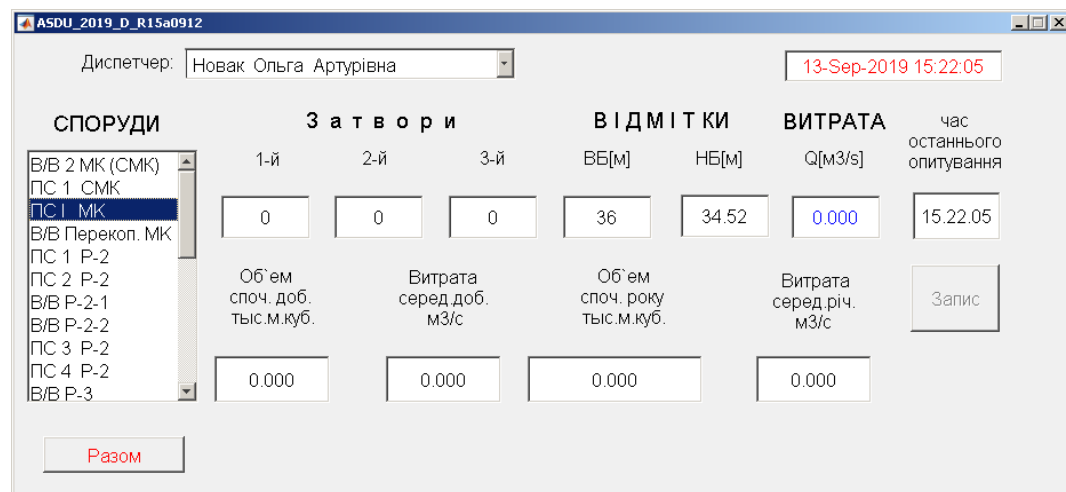**Figure 8.** ACDU system window after selecting the next dispatcher

Figure 9. Window of the ACDU program after selecting the hydrotechnical structure "PS I MK"

3. *Enter information about the state of the hydrotechnical structure at the initial moment of time (beginning of the day):*
   - In the "Date - Time" window, set the beginning of the day.

Figure 10. ACDU program window after setting the time according to the beginning of the day

- Set the appropriate values in the "Close" and "MARKS" windows. In the "Consumption" window, the consumption value will be automatically displayed, accurate to the liter. When working with the "Close" and "MARKINGS" windows, the content of the "Date - Time" window does not change and the "Record" button becomes available. In the "Rest volume" windows add.", "Expenditures in add.", "Volume rest. of the year", "Expenses among. thing." corresponding values of the parameters calculated with respect to the time specified in the "time of the last survey" window are displayed. Negative values in the program start-up mode are due to the negative value of the time interval between the "time of the last survey" and the beginning of the day.
- In the window "Begining volume for a day" enter a zero value. In the window "Begining volume for a year" enter a zero or real value.

4. Record information about the state of the building at the beginning of the day.

To manually record information in the archive file about the state of the building, press the "Record" button with the left key of the "mouse" manipulator.
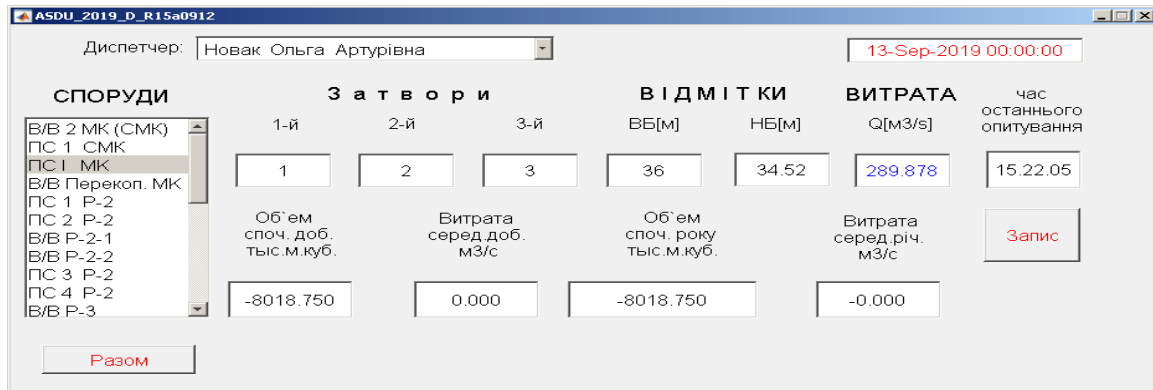

Figure 11. The window of the ACDU program after entering primary information about the state of the object at the beginning of the day
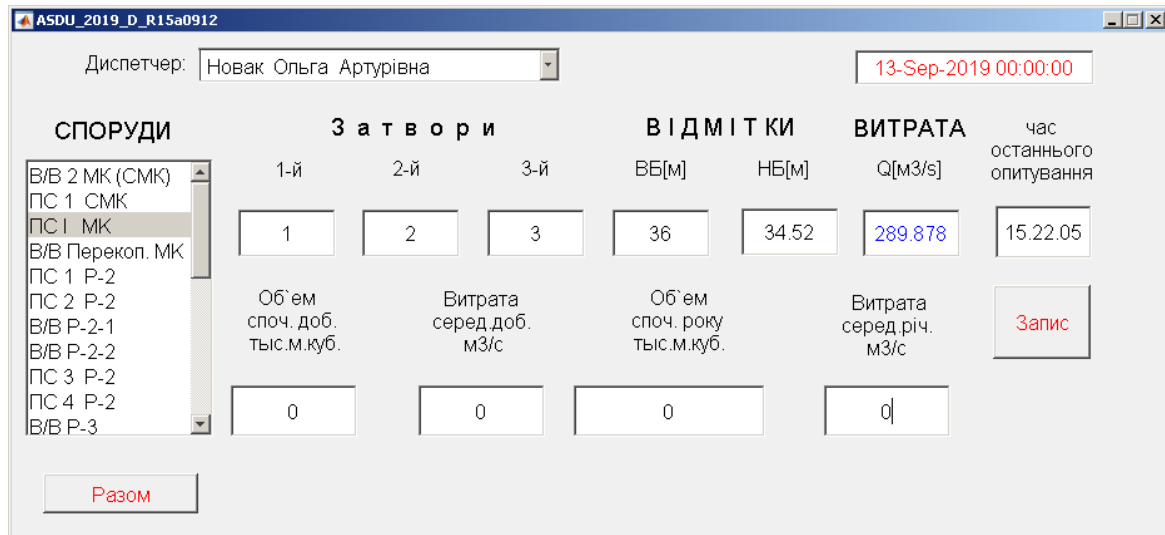

Figure 12. The window of the ACDU program after entering primary information about the state of the object and integral indicators at the beginning of the day

5. Check information about the state of the hydrotechnical structure at the beginning of the day.

To check the entered and recorded information, it is necessary to select the hydrotechnical structure in the "STRUCTURES" menu again with the left key of the "mouse" manipulator. At the same time, in the windows of primary information ("Close", "MARKS"), the values for the "time of the last survey" are displayed, and in the windows of integral indicators ("Volume of initial add.", "Consumption avg. add.", "Vol. ``beginning of the year", 'Avg. of the year", the values listed at the time indicated in the "Date - Time" window are displayed. For other structures, actions for recording primary and integral information are similar to points 1 - 5. When starting the program, it is not necessary to choose a moment of time - the beginning of the day, it can be any moment of time for which all the information is available (for example, the previous dispatch hour).

6. Record information about the current state of hydrotechnical structures

After starting the program and setting the initial values, the work of the operator (dispatcher) consists in receiving primary information about the state of objects as it is received. All manual changes to the information in the "Close", "MARKS", and "DISCHARGE" cells lead to the activation of the "Record" button, but only after pressing it is recorded in the archive file and state database, which is taken into account in further calculations.
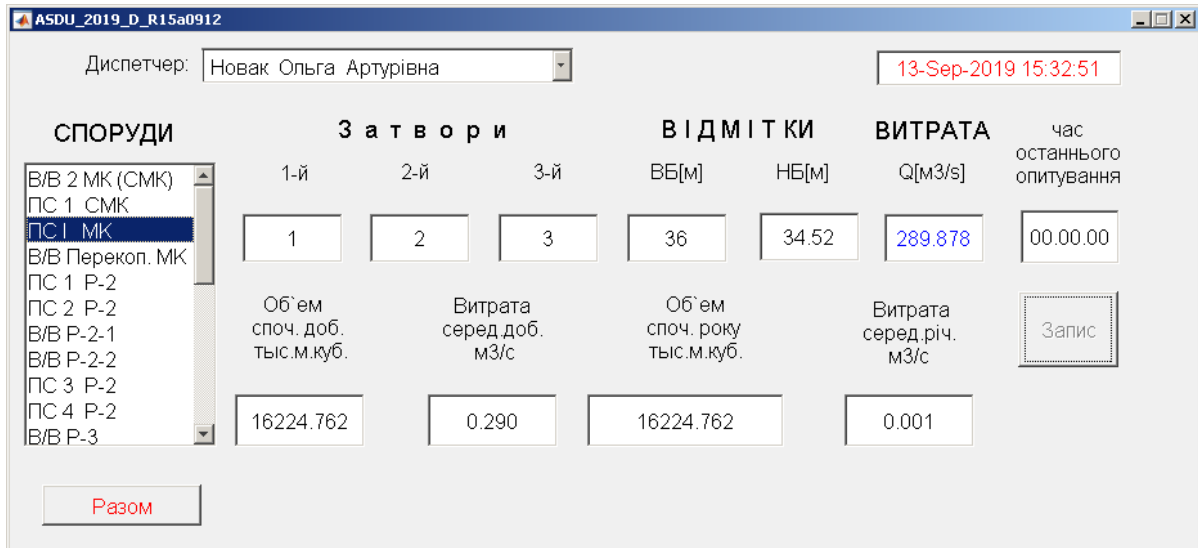
Figure 13. ACDU program window after entering and recording primary information
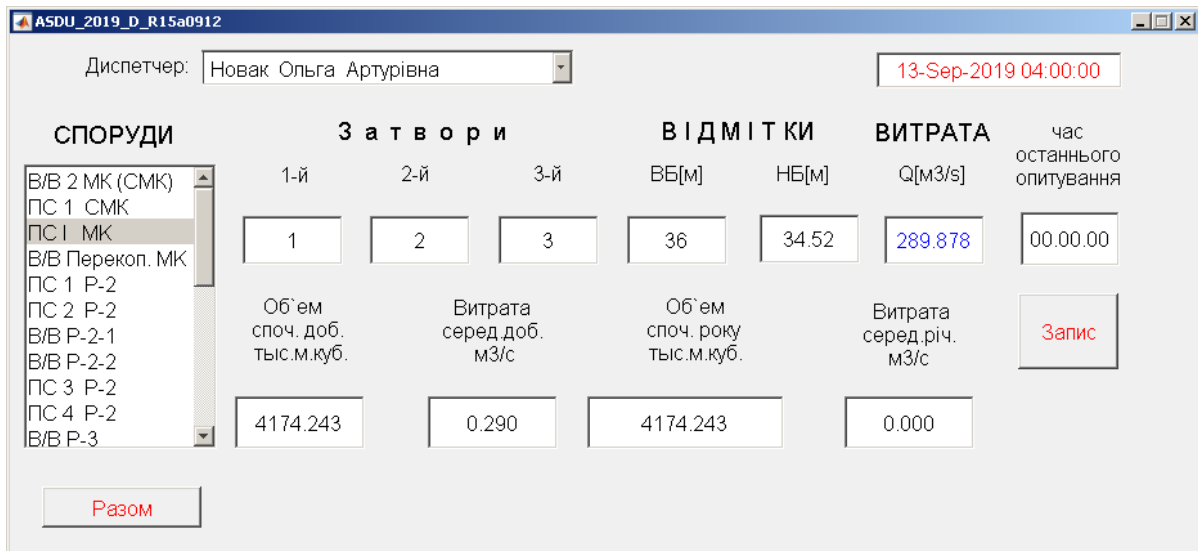
Figure 14. ACDU program window after entering primary information (at 4:00:00)
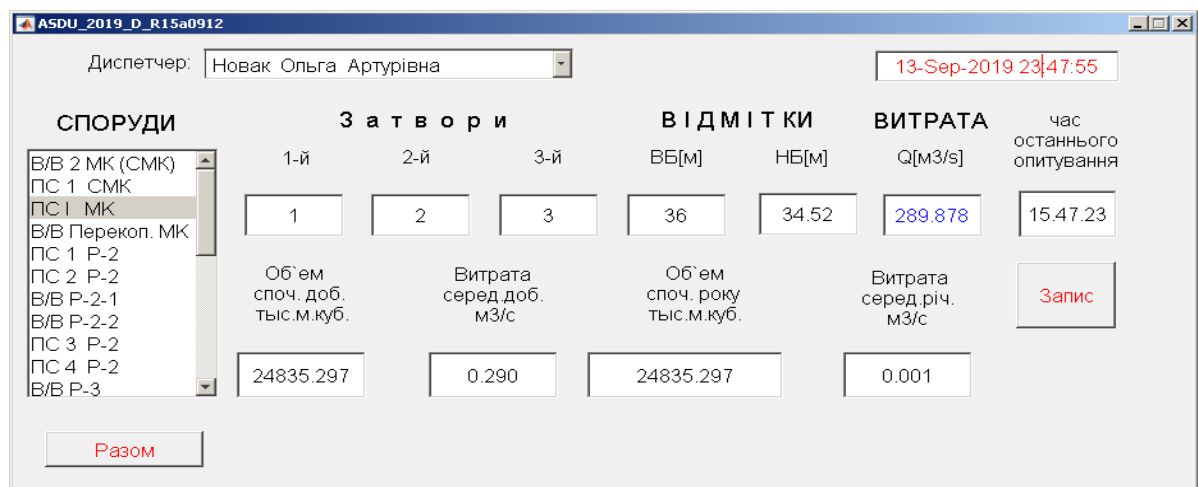
Figure 15. ACDU program window after entering primary information (at 23:47:55)

The "Whole" button allows you to fix the time at the end of the day and get the extrapolated values of the integral indicators. When you click the "Whole" button, the "00" button appears to the right of

the "Date - Time" window, which allows you to speed up the time setting to the corresponding beginning of the day when starting or restarting the program.
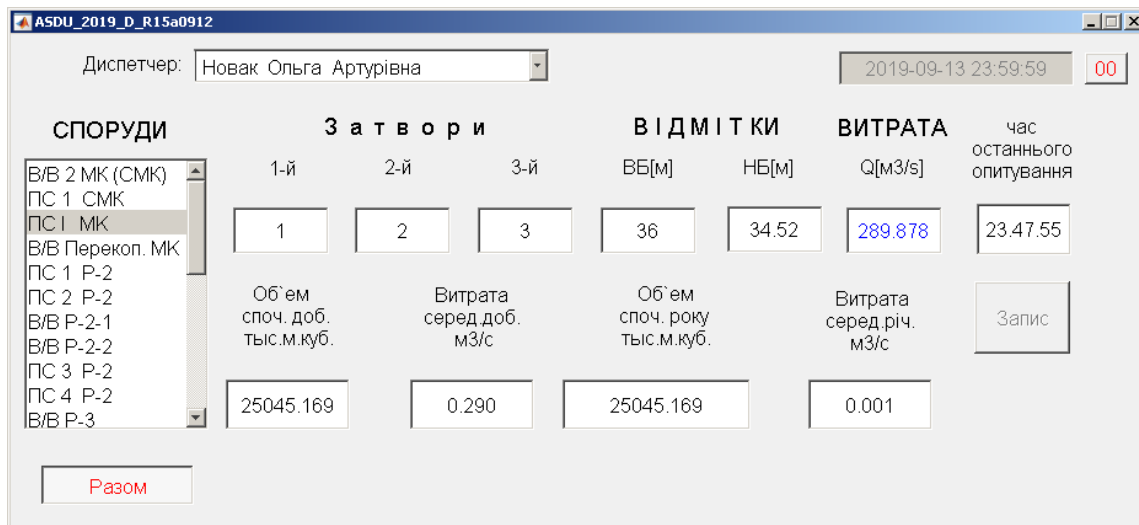

Figure 16. ACDU program window after entering primary information at 23:47:55 and pressing the "Whole" and "Record" buttons
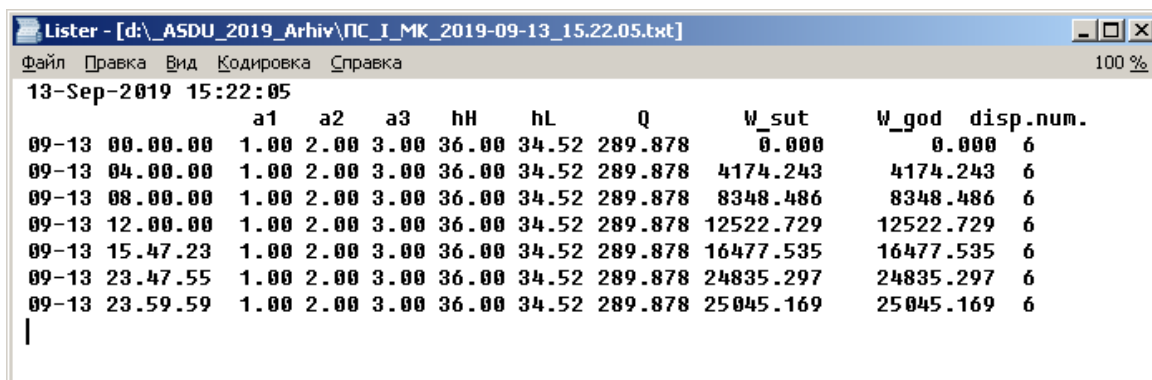

Figure 17. Records of the archival file of the supporting structure after recording information at 23:59:59

Working with structures such as a pumping station is similar to a supporting structure. Differences only in the calculation of integral indicators. For supporting structures, cost integration over time is performed using the trapezoid method, and for pumping stations using the rectangle method.

4. Conclusions

An architecture for an intelligent control system for an irrigation complex is proposed, taking into account actual moisture reserves. It allows you to both optimize irrigation rates depending on the level of actual moisture reserves in field areas, and ensure optimal operation of sprinkler equipment in each irrigation area through the introduction of neurocontrollers into the control system.

The combination of digital technologies and intelligent equipment control systems can significantly reduce deviations, thus optimizing irrigation quality parameters. The developed system can be in demand due to the ease of its use both in decision support systems and the possibility of direct implementation in control systems of irrigation complexes when developing modern sprinklers.

The software product is proposed for performing the dispatching task of water distribution on irrigation hydromelioration systems, which, in addition to ease of use and operation, allows implementing energy-saving technologies, which will save about 15–30% of electricity and, accordingly, money annually.

5. References

[1] Wang, J. H., Lin, G. F., Chang, M. J., Huang, I. H., & Chen, Y. R. (2019). Real-time water-level forecasting using dilated causal convolutional neural networks. *Water resources management*, *33*, 3759-3780.

[2] Chang, F. J., Chen, P. A., Lu, Y. R., Huang, E., & Chang, K. Y. (2014). Real-time multi-step-ahead water level forecasting by recurrent neural networks for urban flood control. *Journal of Hydrology*, *517*, 836-846.

[3] Ren, T., Liu, X., Niu, J., Lei, X., & Zhang, Z. (2020). Real-time water level prediction of cascaded channels based on multilayer perception and recurrent neural network. *Journal of Hydrology*, *585*, 124783.

[4] Wei, C. C. (2020). Comparison of river basin water level forecasting methods: sequential neural networks and multiple-input functional neural networks. *Remote Sensing*, *12*(24), 4172.

[5] Digital's Kompensation sverfahren zur Verbesserung von Messfuhlern. Erb. K., Fisher P. "Bulletin SEV/VSE", 1989, 80, №7, 8, 365-368.

[6] L. Kuzmych, D. Ornatskyi, V. Kvasnikov, A. Kuzmych, A. Dudnik and S. Kuzmych, Development of the Intelligent Instrument System for Measurement Parameters of the Stress - Strain State of Complex Structures, 2022 IEEE 4th International Conference on Advanced Trends in Information Theory (ATIT), Kyiv, Ukraine, 2022, pp. 120-124, DOI: 10.1109/ATIT58178.2022.10024222.

[7] K.B. Klassen, Basis of Measurements, Electronic Methods and Devices in Measuring Equipment. M.: Postmarket, 2000. – 352 p.

[8] J. Uikzer, Connectivity: Intelligent Sensors or Intelligent Interfaces, Sensors and Systems. – 2002.- №10. – P.50-55.

[9] G. Rus, S. Y. Lee, S. Y. Chang, S. C. Wooh, Optimized Damage Detection of Steel Plates from Noisy Impact Test, International Journal for Numerical Methods in Engineering. - 2006. - Vol. 68, Issue 7. - P. 707-727. DOI: 10.1002/nme.1720.

[10] A. Schroder, J. Rautenberg, B. Henning, Evaluation of Cost Functions for FEA Based Transducer Optimization, Physics Procedia. - 2010. - Vol. 3, Issue 1. - P. 10031009. DOI: 10.1016/j.phpro.2010.01.129.

[11] I. Korobiichuk, L. Kuzmych, V. Kvasnikov, The System of the Assessment of a Residual Resource of Complex Technical Structures. MECHATRONICS 2019: Mechatronics 2019: Recent Advances Towards Industry 4.0. pp 350-357. https://doi.org/10.1007/978-3-030-29993-4_43.

[12] J. Li, P. Liu, H. Ding, W. Cao, Modeling Characterization and Optimization Design for PZT Transducer Used in Near Field Acoustic Levitation, Sensors and Actuators A: Physical. – 2011. – Vol. 171, Issue 2. – P. 260–265. DOI: 10.1016/j.sna.2011.06.020

[13] J. Corcoran, K. Poulton, Analog to Digital Converters: 20 years of Progress in Agilent Oscilloscopes, Agilent Measurement J. 2007 Issue 1. p. 35-40.

[14] Delta Sigma Data Converters. Theory, Design, and Simulations. Edited by S.Norsworthy, R.Schreirer, G.Temes. IEEE Press, IEEE Order Number PC3954.

[15] M. Rakushev, S. Kovbasiuk, Y. Kravchenko, & O. Pliushch, Robustness Evaluation of Differential Spectrum of Integration Computational Algorithms, In 2017 4th International Scientific-Practical Conference Problems of Infocommunications (2017, October). Science and Technology (PIC S&T) (pp. 21-24). IEEE.

[16] Y. Kravchenko, O. Starkova, K. Herasymenko, & A. Kharchenko, Peculiarities of the IPv6 Implementation in Ukraine, In 2017 4th International Scientific-Practical Conference Problems of Infocommunications (2017, October). Science and Technology (PIC S&T) (pp. 363-368). IEEE.

[17] E. Ozalevli, Lo Haw-Jing, P.E. Hasler, Binary-Weighted Digital-to-Analog Converter Design Using Floating-Gate Voltage References, IEEE Transactions on Circuits and Systems I: Regular Papers 2008, Volume: 55, Issue: 4, Page(s): 990 – 998.

[18] L. Kuzmych, L. Volk, A. Kuzmych, S. Kuzmych, G. Voropay and V. Polishchuk, Simulation of the Influence of Non - Gaussian Noise During Measurement, 2022 IEEE 41st International Conference on Electronics and Nanotechnology (ELNANO), 2022, pp. 595-599, DOI: 10.1109/ELNANO54667.2022.9927008.

[19] L. Kuzmych, G. Voropay, A. Kuzmych, V. Polishchuk, A. Kuzmych, Concept of Creation of the Automated System of Remote Deformation Monitoring and Control of the Technical Condition of Engineering Infrastructure, International Conference of Young Professionals «GeoTerrace-2022», Oct 2022, Volume 2022, p.1 - 5 DOI: https://doi.org/10.3997/2214-4609.2022590076 (Scopus)

[20] L. Kuzmych, M. Voloshin, A. Kuzmych, S. Kuzmych, V. Polishchuk, Experimental Studies of Deformation Monitoring in Metal Structures Using the Electromagnetic Method. International Conference of Young Professionals «GeoTerrace-2022», Oct 2022, Volume 2022, p.1 - 5 DOI: https://doi.org/10.3997/2214-4609.2022590078

[21] K.J. Åström, T. Hägglund, Avanced PID Control. ISA-The Instrumentation, Systems and Automation Society, 2006. 460 p.

[22] A. O'Dwyer, Handbook of PI and PID Controller Tuning Rules, 3rd edn. Imperial College Press, London, 2009. 599 p.

[23] R. Zurawski, Integration Technologies for Industrial Automated Systems. Industrial information technology Series. CRC Press, Taylor & Francis Group, Boca Raton, 2007. 539p.

[24] M. Masum Jujuli, Analytical Design of PID Controller for Enhanced Disturbance Rejection of Processes without Time Delay. Graduate School of Yeungnam University,2010.

[25] M.A. Johnson, M.H. Moradi, PID Control. New Identification and Design Methods. Springer, London, 2005. 543 p.

[26] S. Keil, Beanspruchungsanalyse mit Dehnungsmessstreifen, Stress Analysis Using Strain Gages – Cuneus Verlag, 1995. – 353 p.

[27] T. Harada, N. Ishikawa, T. Kanda, K. Suzumori, Y. Yamada, K. Sotowa, Droplet Generation Using a Torsional Langevin-Type Transducer and a Micropore Plate, Sensors and Actuators, A: Physical. - 2009. - Vol. 155, Issue 1. - P. 168-174. DOI: 10.1016/j.sna.2009.08.007.

[28] Iatsyshyn, A., Iatsyshyn, A., Kovach, V., Zinovieva, I., Artemchuk, V., Popov, O., . . . Turevych, A. (2020). Application of open and specialized geoinformation systems for computer modelling studying by students and PhD students. Paper presented at the CEUR Workshop Proceedings, , 2732 893-908.

[29] Hubanova, T., Shchokin, R., Hubanov, O., Antonov, V., Slobodianiuk, P., & Podolyaka, S. (2021). Information technologies in improving crime prevention mechanisms in the border regions of southern Ukraine. Journal of Information Technology Management, 13, 75-90. doi:10.22059/JITM.2021.80738

[30] Kanmani, R., Muthulakshmi, S., Subitcha, K. S., Sriranjani, M., Radhapoorani, R., & Suagnya, N. (2021, March). Modern irrigation system using convolutional neural network. In *2021 7th International Conference on Advanced Computing and Communication Systems (ICACCS)* (Vol. 1, pp. 592-597). IEEE.

[31] Agyeman, B. T., Sahoo, S. R., Liu, J., & Shah, S. L. (2022). LSTM-based model predictive control with discrete actuators for irrigation scheduling. *IFAC-PapersOnLine*, *55*(7), 334-339.

[32] Nadafzadeh, M., & Abdanan Mehdizadeh, S. (2019). Design and fabrication of an intelligent control system for determination of watering time for turfgrass plant using computer vision system and artificial neural network. *Precision Agriculture*, *20*(5), 857-879.

[33] Chen, H., Quan, L., Wang, W., Chen, X., & Duan, C. (2019). Risk evaluation of irrigation water transfer project dispatching based on cloud model and possibility measures. *Water Saving Irrigation*, (1), 112-117.

[34] Naval, N., Sánchez, R., & Yusta, J. M. (2020). A virtual power plant optimal dispatch model with large and small-scale distributed renewable generation. Renewable Energy, 151, 57-69.

6. Appendix

A. Contents of the primary record of the archival file

Figure A1. Contents of the primary record of the archival file of the supporting structure
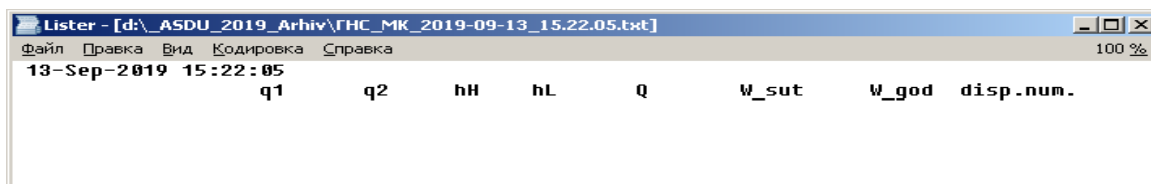

Figure A2. Contents of the primary record of the archive file of the pumping station

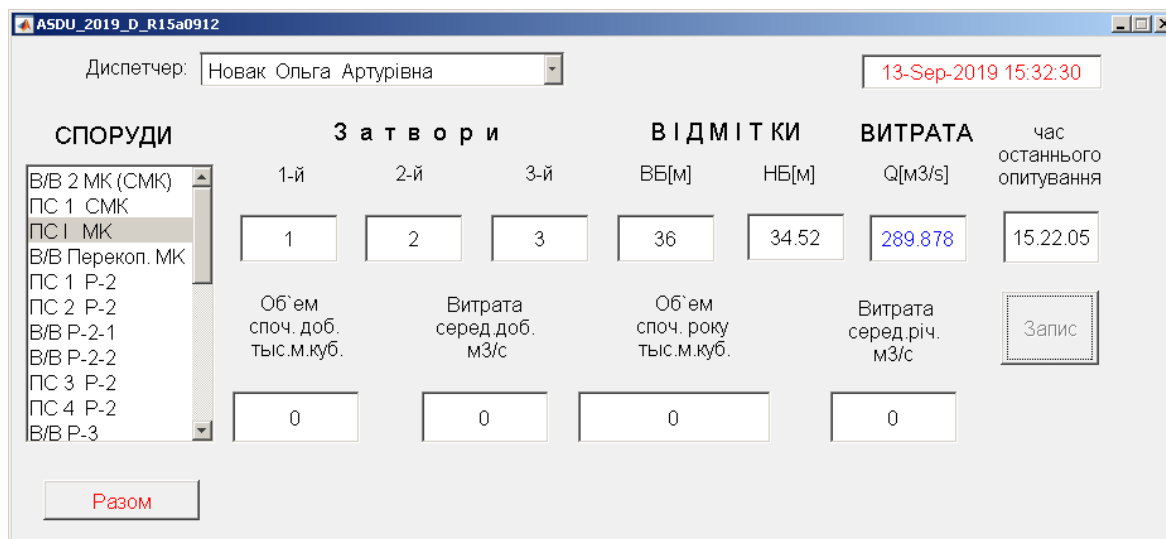# B. ACDU program window after entering and recording primary information

Figure B1. ACDU program window after entering and recording primary information about the state of the object and integral indicators at the beginning of the day
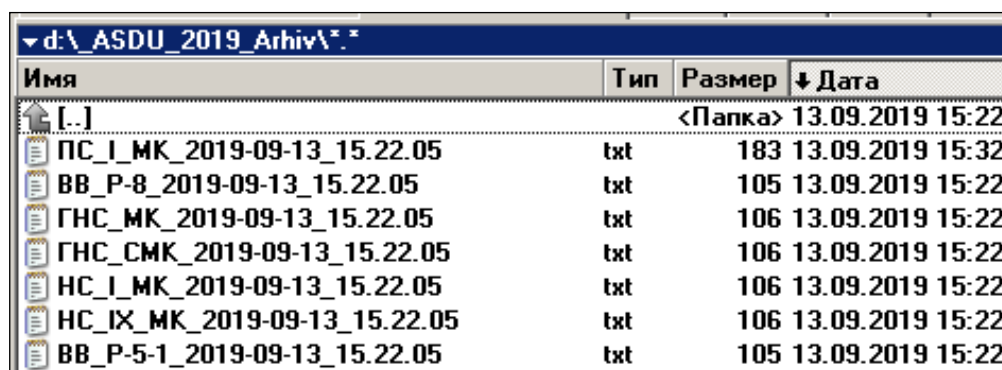
Figure B2. Contents of archive files folder after recording information
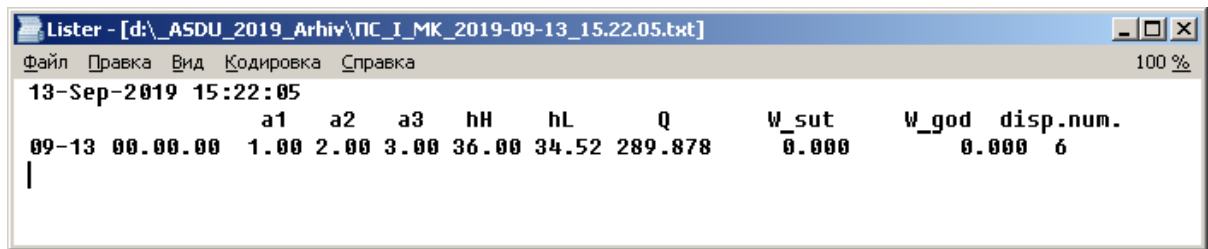
Figure B3. Contents of the record of the archival file of the supporting structure after recording the information

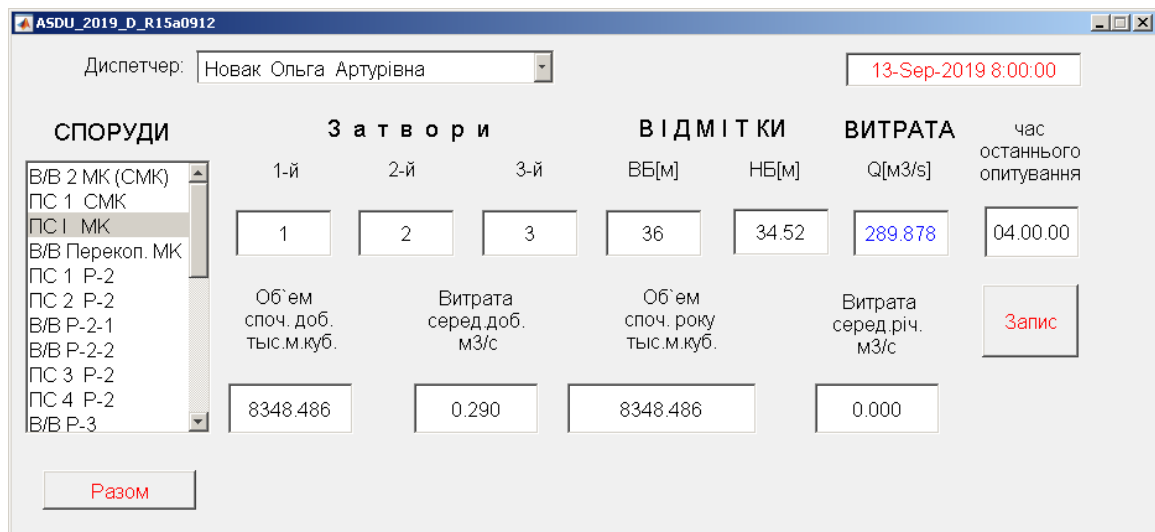# C. ACDU program window after entering and recording primary information

Figure C1. ACDU program window after entering primary information (at 8:00:00)
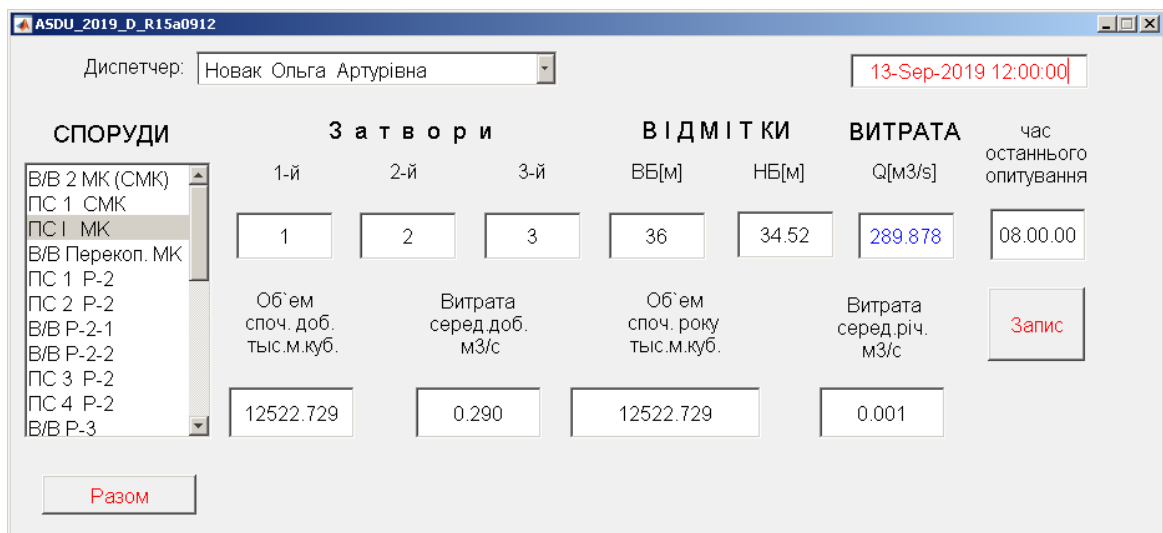

Figure C2. ACDU program window after entering primary information (at 12:00:00)
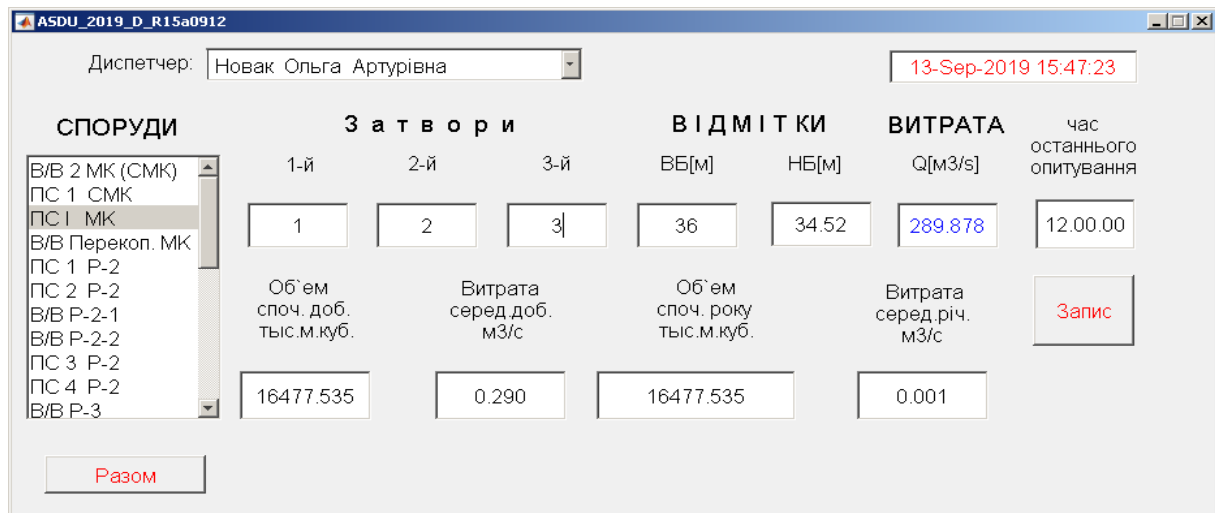
Figure C3. ACDU program window after entering primary information (at 15:47:23)
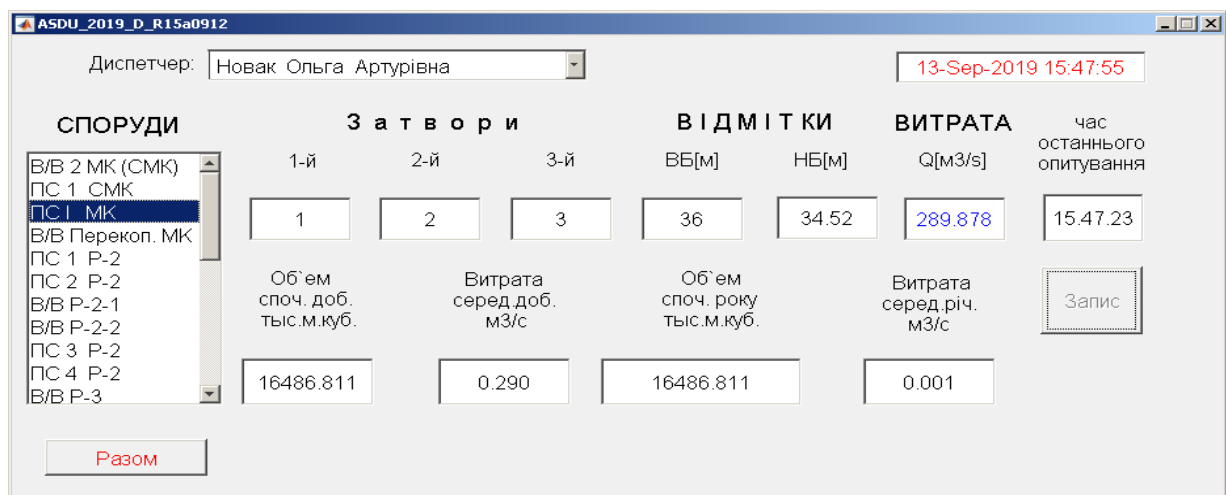

Figure C4. ACDU program window after entering and recording primary information (at 15:47:23)
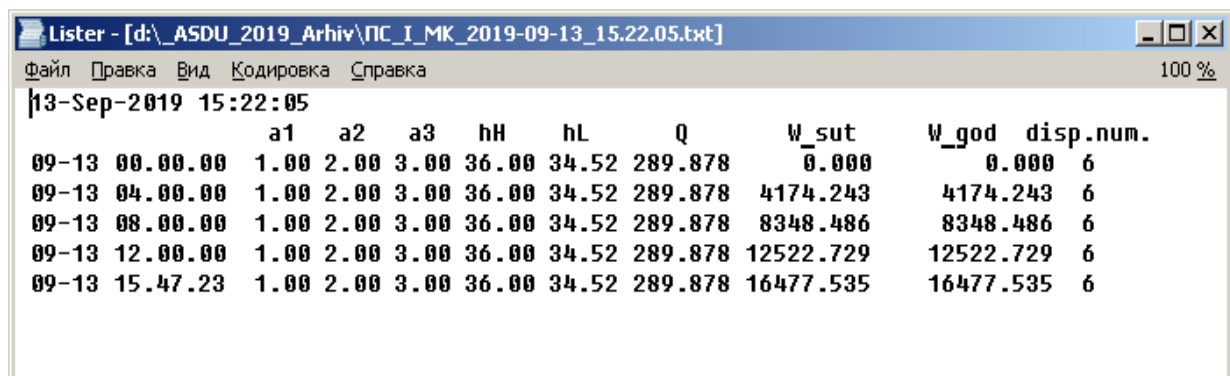

Figure C5. Content of the record of the archival file of the supporting structure after recording the information (at 15:47:23)