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DEVELOPMENT OF THE SCADA SYSTEM FOR CONTROLLING METEOROLOGICAL FACTORS IN ORDER TO PREVENT NATURAL CATACLISMS

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Summary. *The paper is devoted to the problem of monitoring meteorological precipitation. Since their excessive fallout, namely: 50–60 mm/h, results in flooding of residential areas or agricultural land. The scientific value of the work is in the fact that the architecture of the system for monitoring meteorological factors (its lower level) has been developed. In comparison with the known ones, it includes functions and comparisons of current values with specified values of precipitation, atmospheric pressure, air temperature and soil moisture (critical). The practical value of the work lies in the fact that, on the basis of theoretical studies generalization, two-level automated system for monitoring meteorological factors has been developed, In this system the lower level makes it possible to compare current values with set values, and the upper level of the system is SCADA WINCC project.*

Key words: *meteorological factors, monitoring, two-level automated system, ecological safety.*

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Statement of the problem. In Ukraine, up to 150 cases of natural meteorological phenomena are observed annually. Heavy rains, snowfall, ice, and fogs are the most frequent occurrences Dust storms and ice freezes are not so common. Dangerous meteorological phenomena occurring in Ukraine are: heavy rains (Carpathian and Crimean mountains); hail (the entire territory of Ukraine); extreme heat (steppe zone); dry winds, droughts (steppe and eastern forest-steppe zones); hurricanes, squalls, tornadoes (most of the territory); dust storms (south-east of the steppe zone); heavy fogs (south-east of the steppe zone); severe snowstorms (south-east of the steppe zone); snow drifts (Carpathians); significant icing (steppe zone); severe frost (north of Polissia and east of the forest-steppe zone); in addition, storms, hurricane winds, tornadoes, heavy rains, icing of buildings and vessels, heavy fogs, blizzards and ice occur along the coast and in the waters of the Black and Azov Seas. The Ukrainian Carpathians are characterized by heavy rains that cause flooding and mudflows, hail, strong winds, fogs, blizzards, and heavy snowfall [1, 2, 3].

Control over meteorological factors (atmospheric pressure, air temperature, precipitation and soil moisture) is an important scientific task, as their excess results in natural disasters such as floods, suffusion and mudflows. Insufficient and untimely information on meteorological factors, as well as the lack of modern, complete and integrated protective complex, result in annual losses in the agricultural, industrial and social sectors of the economy, as well as human victims.

Having analyzed all of the above mentioned, for deeper investigation and understanding of the meteorological factors impact on the environment, the structural scheme [4] which takes into account the morphometric characteristics of the river basins is proposed. It is also determined that the main and the most dangerous meteorological factors that have the greatest impact on the occurrence of mudflows or suffusions are precipitation and soil moisture.

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The structural model is presented in Fig. 1.

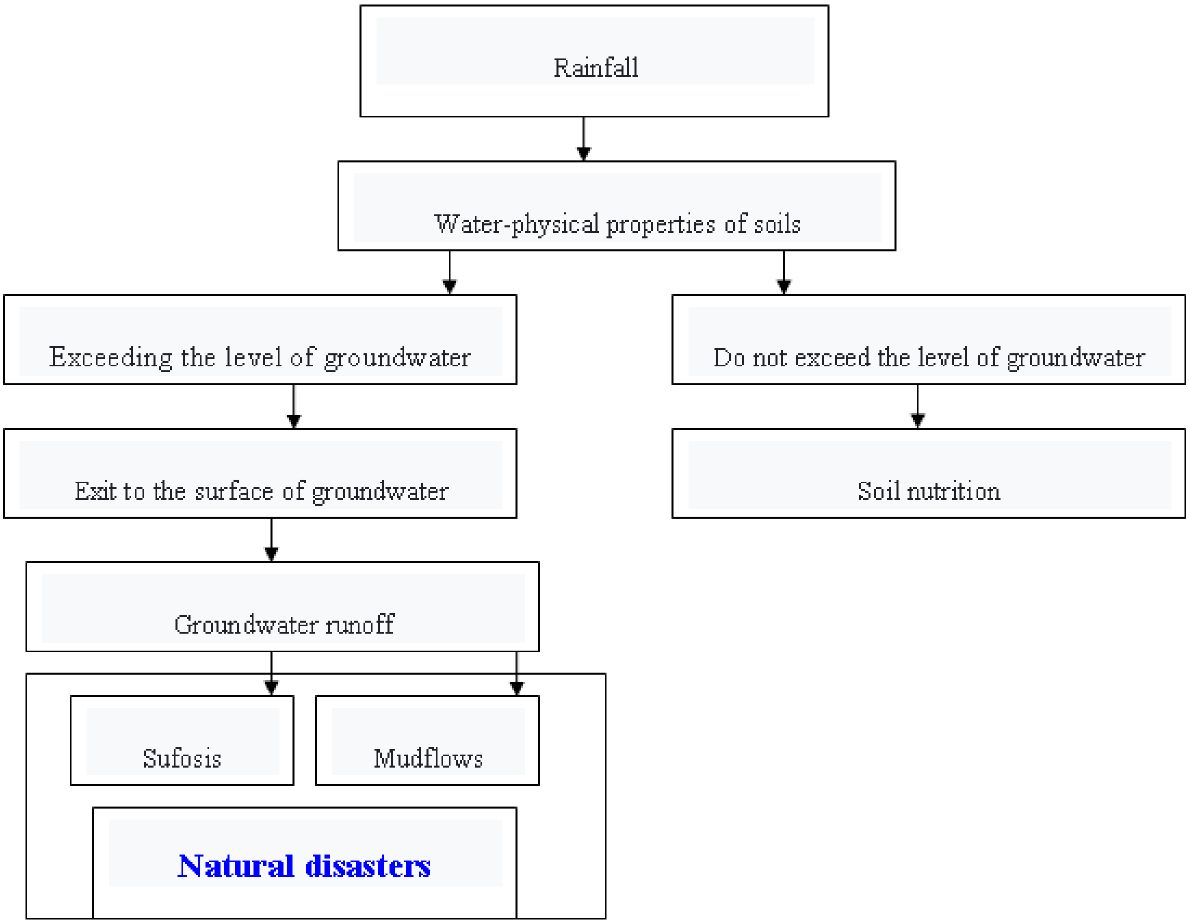

Figure 1. Structural model of meteorological factors impact on the environment

The structural model describes that precipitation, temperature, and soil moisture are the main climatic factors of runoff. Among these listed factors, precipitation is considered to be the most important, as it directly affects runoff. For example, precipitation on waterlogged soils intensifies sloping runoff 1.5–12 times stronger in comparison with precipitation on relatively dry soils [4].

Suffusion processes often interfere with the construction, so humanity tries to prevent its further manifestation. In order to prevent suffusion, the following measures are taken: prevention of inflow and movement of water in rocks: regulation of the surface runoff, interception of groundwater by drainage devices; protection of clay rocks from weathering by means of installing protective coatings of sand and crushed clay; installation of surface drains (to drain underground water and prevent particles from being washed away); reduction of the speed of groundwater movement by changing the building structure. For example, clay piles which lengthen the filtration path and reduce pressure gradients are arranged under dams; artificial improvement of rock properties by means of silicification, cementation, etc.

Mudflows (muds) are short-term mountain flows that consist of the mixture of water and large amount of solid material. They occur as the result of rains, intensive melting of snow and ice, debris and dams in valleys, where there are large reserves of loose debris material. Mudflows become extremely dangerous natural hydrological phenomenon, when mudflow threatens settlements, railways, highways, irrigation systems and other important objects.

Presented structural model also provides theoretical background for the development of the automated system for meteorological factors monitoring, and makes it possible to identify and take into account dangerous factors in order to prevent natural phenomena, such as suffusion and mudflows.

Therefore, the task of monitoring the output values is relevant in order to prevent or reduce possible losses in the agricultural, industrial and social sectors of the economy from their negative consequences.

Analysis of the available investigation results. Analysis of modern approaches to the organization and implementation of the system of meteorological factors monitoring makes it possible to highlight the main purpose of its operation – to meet the need for information for the integrated eco-system approach and to manage the state of the environment, particularly: suffusion and mudflows.

Flood prevention and control system using wireless sensor networks is presented in paper [5].

It is known that at present, there is a significant number of automated information measuring systems (AIMS) and technical means that are at the stages of development and implementation, namely: «Prykarpattia», «Tysa», «Romania-Ukraine-Moldova» project, a network of automated hydroposts. The main functional purpose of AIMS "Prykarpattia" is the location of hydrometeorological posts with autonomous intelligent detectors that provide automated collection, transmission and accumulation of information about water level and temperature, as well as air temperature [1]. Nowadays, 50 hydrometeorological (measuring water level, precipitation, air temperature) and 13 meteorological (measuring precipitation and air temperature) AIMS «Tysa» have been installed on the territory of Transcarpathian region on the rivers Borzhova, Latorytsa, Rika, Uzh, Bila Tysa, Chorna Tysa, Turia, Kosivska, Teresva and Pinia [1–3].

According to «Romania-Ukraine-Moldova» project, 80 villages of Bukovyna in Ukraine, are provided with precipitation gauges [6]. Regions covered by the program are: in Romania, such districts as Suceava, Botosani, Iasi, Vaslui, Galati and Tulcea; in Ukraine: Odessa and Chernivtsi regions; in the Republic of Moldova: the whole country and additional regions (in Romania: Braila district; in Ukraine: Ivano-Frankivsk region and Vinnytsia region, as well as ten districts: Vinkovetskyi, Chemerovetskyi, Khmelnytskyi, Kamianets-Podilskyi, Letychivskyi, Dunaievetskyi, Dzerzhynskyi, Novoushytskyi, Yarmolynetskyi and Horodetskyi in Khmelnytskyi region and twelve districts Ternopilskyi, Berezhanskyi, Pidgaitsivskyi, Terebovlyanskyi, Monastiriskyi, Gusyatynskyi, Chortkivskyi, Borshchivskyi, Zalishchytskyi and Buchatskyi in Ternopil region. In order to obtain accurate and operational information about the hydrological situation in Prut and Siret basins, a network of automated hydroposts will be built [1, 6]. Detectors at hydroposts will measure the level and flow of water and air every hour, as well as the amount of precipitation. These data will be sent to the regional office of the State Agency for Water Resources. Over time, a special geoportal with different levels of access for specialists, government officials (civil servants) and the population (citizens) will start to function.

In conclusion, it should be noted that the carried out analysis of the existing automated information and measurement systems, as well as technical means of meteorological factors, has a number of disadvantages: high economic costs for the development and implementation of these systems and technical means (AIMS «Tysa» is 225,000 euro, 3 hydroposts of AIMS «Prykarpattia» –0.5 million hryvnias, comprehensive nationwide anti-flood monitoring system – 14 million 680 thousand hryvnias); inadequate funding from the state does not allow to create sufficient number of AIMSs and hydroposts in order to ensure environmental safety; it does not take into account water-physical properties of soils; the duration of the process of determining soil moisture is 1.5–2 days, which results in the delay in making technological decisions, because in case of significant precipitation or drought, soil moisture can change significantly during this time; labor intensity of the method and equipment cost specify the high cost of obtaining the necessary information about soil moisture.

Analysis of literature sources on the investigation of the system of meteorological factors monitiring showed that they are an important natural factor of negative impact on all sectors of the economy, therefore the objective of this thesis is to ensure environmental safety by controlling and forecasting the level of flood waters.

Analysis of the existing systems for controlling meteorological factors and technical means also showed that the humidity of the basin (soil moisture) and the implementation of data archiving of natural factors are uncontrolled output values.

One of the solutions is the development of a new system for meteorological factors monitoring.

In order to develop the given system, it is necessary to: develop the theoretical prerequisites of the system for meteorological factors monitoring; develop the automated system for natural factors monitoring, such as the amount of precipitation, soil moisture, air temperature, and atmospheric pressure; implementation of natural factors archiving.

Based on the above mentioned analysis of the systems and technical means for meteorological factors control, it is determined that the existing systems control mainly air temperature, atmospheric pressure, and the amount of atmospheric precipitation, and there is no soil moisture monitoring and its archiving in the database of the developed systems. This indicator belongs to water-physical properties of soils and is one of the main indicators of soil moisture in river basins adjacent to residential areas or agricultural lands.

As far as the existing systems for meteorological factors controlis concerned, they have not found wide practical application due to their low efficiency, significant cost, and they do not take into account water-physical properties of soils, and the status of controlled values is not displayed (archiving and output of emergency messages).

The objective of the paper is the development of automated system for meteorological factors monitoring in order to prevent natural disasters (high water, floods, mudflows).

Statement of the problem. To achieve the aim of the investigation, the following tasks are solved: analysis of the latest research and publications is carried out; theoretical prerequisites for the system development is created (structural diagram); the automated system for meteorological factors monitoring is developed; conclusions regarding the obtained results are formed.

Analysis of numerical results. On the basis of theoretical prerequisites for the development of the automated system for meteorological factors monitoring, as well as the structural scheme of the initial values influence on the environment and the proposed software tools, the creation of the system lower level in STEP 7 software environment [7] took place with the determination of the type and directory for saving the files of two-level project system.

The automation station (AS) based on S7-300 controller (Fig. 2) consists of: the rack providing mechanical and electrical connections between S7-300 modules; power supply (PS) for voltage converting (alternating current 120/230 V or direct current 24 V) into 5 V and 24 V (direct current) into the voltage required to power supply of S7-300; CPU (Central Processing Unit) [7].

The structure of the program consists of four functions FC1, FC2, FC3 and FC4 (Fig. 3), namely: FC1 is the function of comparing current values with the set values of atmospheric precipitation amount (critical); FC2 is the function of comparing the current values with the set critical values of soil moisture; FC3 is the function for outputting current values from the atmospheric pressure sensor; FC4 is the function for outputting current values from the air temperature sensor.

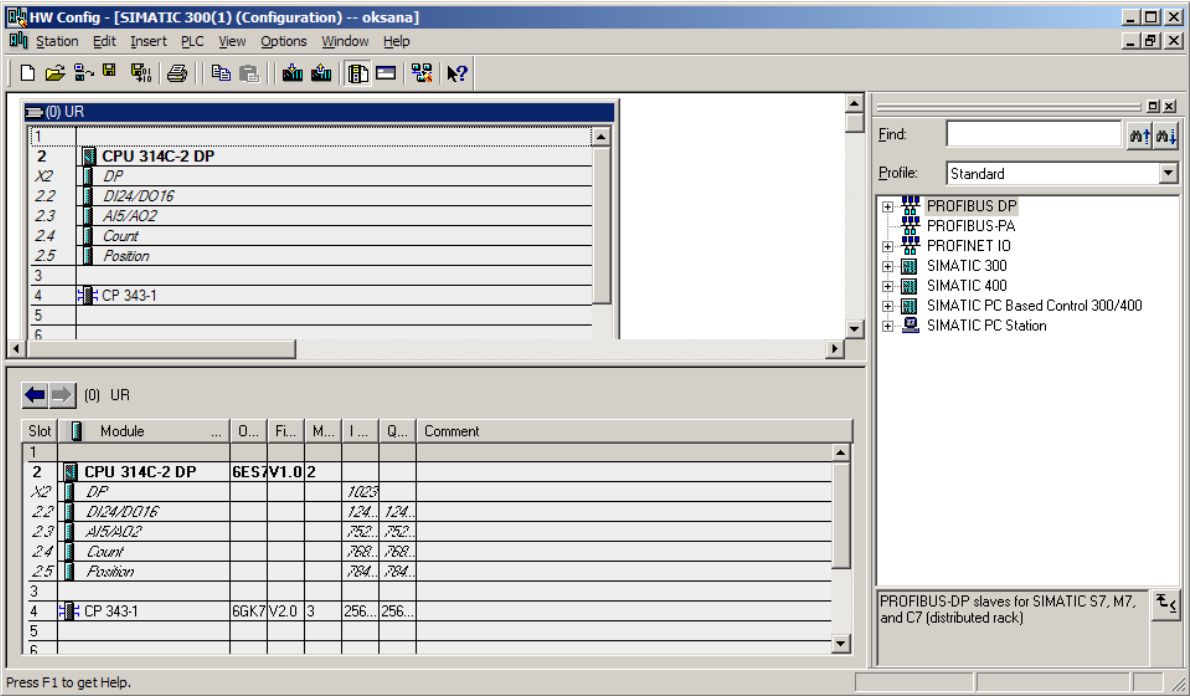

Figure 2. S7-300 station configuration

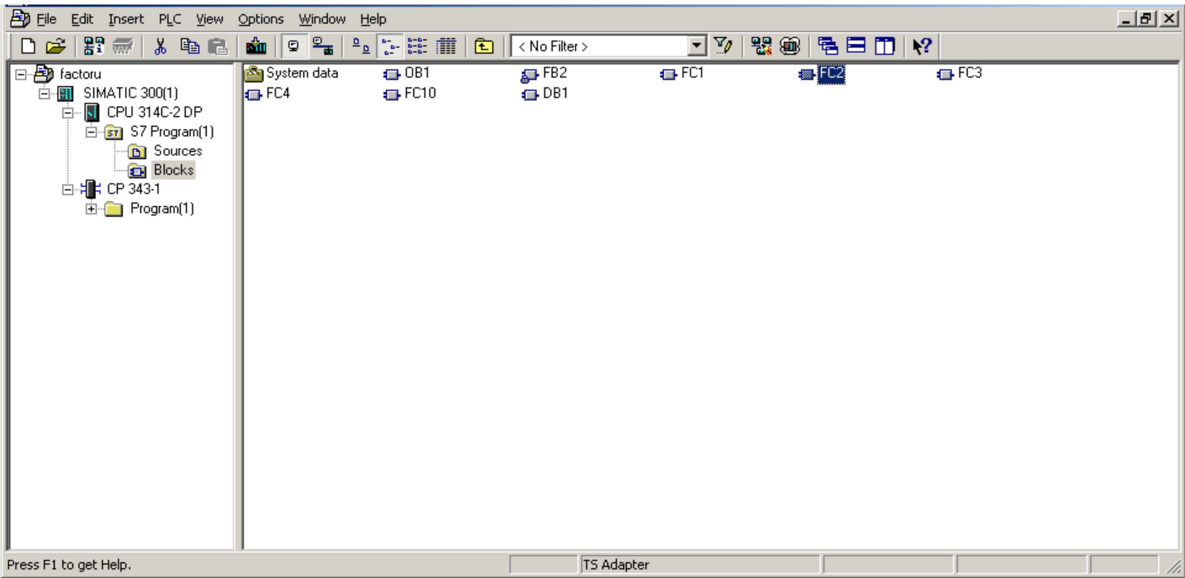

Figure 3. Program structure

The following labels also correspond to the output values (Fig. 4): MD130 is the value of soil moisture sensor, MD100 corresponds to the value of the sensor measuring the amount of atmospheric precipitation, and MD120 forms the critical value, MD140 is for the critical value of soil moisture, MD170 is the critical temperature value, MD190 is the value of atmospheric pressure sensor, MD200 is the critical value of atmospheric pressure, then the order of their creation corresponds to the process shown in Fig. 4.

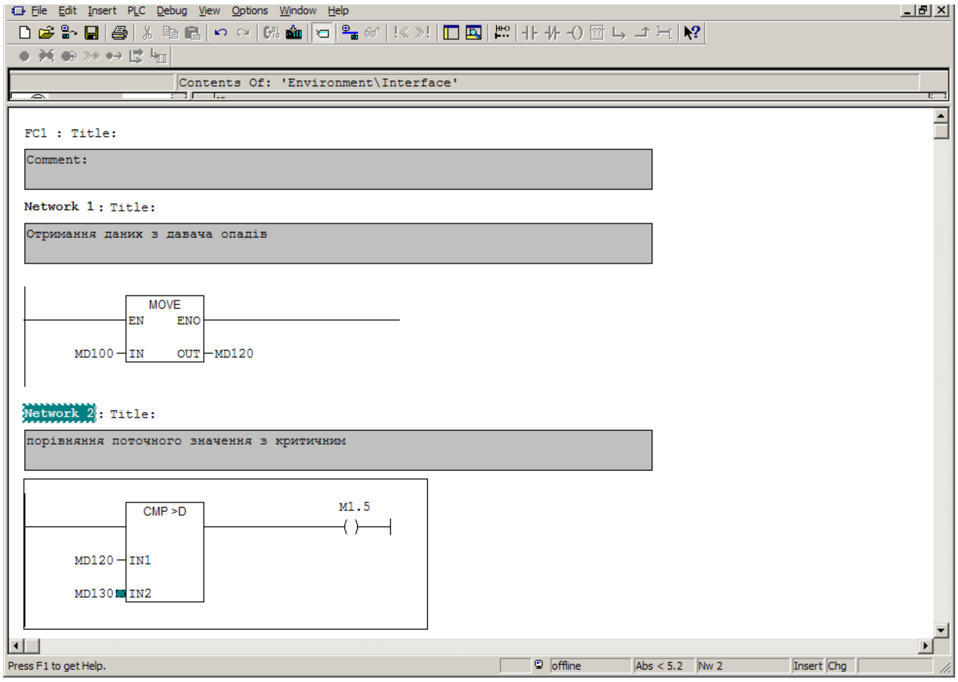

Figure 4. Comparison of the precipitation amount (current and critical)

FC10 function (Fig. 3) is responsible for normalizing analog signals from four sensors of meteorological factors at the selected monitoring point, CP 343-1 is the interface module for communication via TCP/IP protocol of Ethernet network, which is necessary for communication with GSM modem. FC10 function also uses FB2 CRP_IN10 function block for normalizing signals from sensors (Fig. 5).

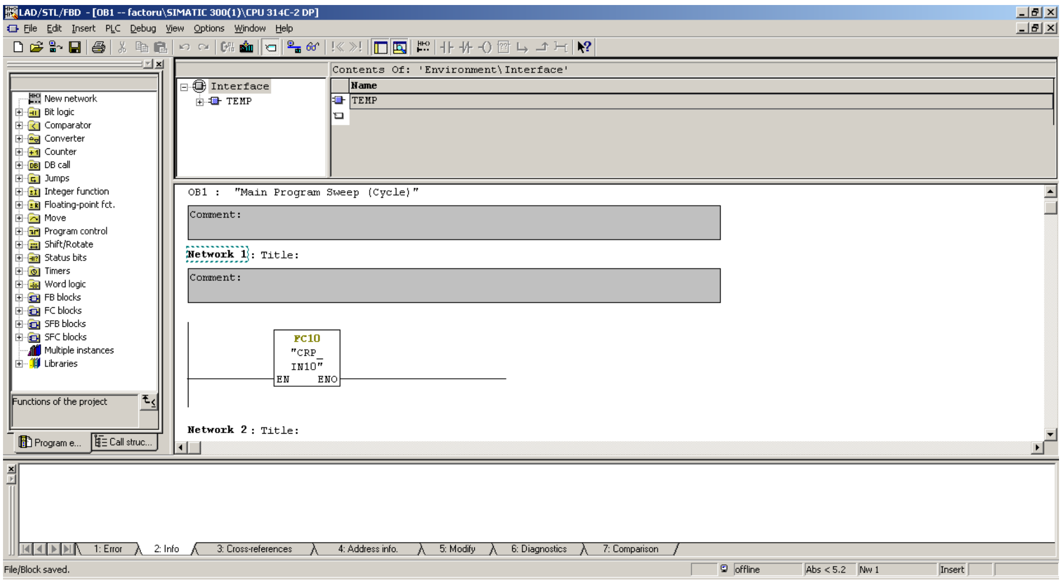

Figure 5. Display of FC10 function

CRP_IN block is used to convert values from the range of analog inputs and outputs. INV_PER variable takes the value of PIW752 for address data input (Fig. 6).

Real value is entered into FACTOR input value in order to scale the output data. OFFSET input is of Real type, which is responsible for indicating the constant offset of this value; in START_ON – the Boolean type, when it is set to 1, STARVAL value is transferred to OUTV output value. When START_ON is 0, the normalized signal from INV_PER to OUTV is transmitted, and from the output of the given value, data is assigned to MD20 memory area.

The developed functions FC1, FC2, FC3, FC4 and FC10 will be also used for project development in SCADA WINCC. The creation of tags in SCADA is shown in Figure 6 and their main purpose is the application for data display. The main tags [8] are the output data from the sensors, i.e., their current values of precipitation, air temperature, soil moisture, and atmospheric pressure, as well as setting their critical values. That is, eight tags are used (Fig. 6).

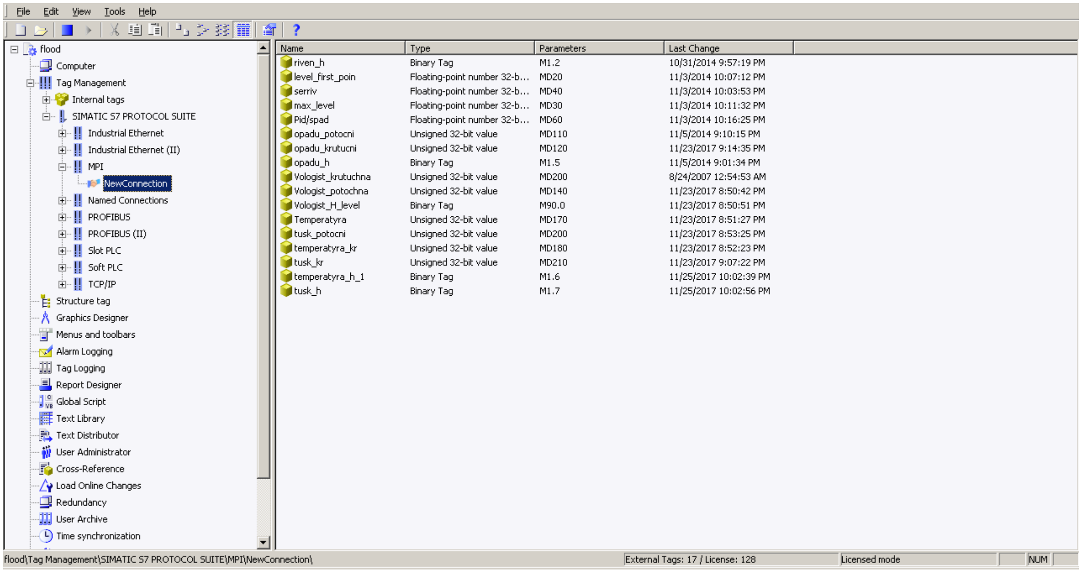

Figure 6. Tags in WINCC

The list of possible emergency messages includes the following texts (Fig. 7): critical level; critical amount of precipitation; critical temperature; critical soil moisture. Connecting the tags for archiving data from sensors is shown in Figure 8. Archives creation is required for numerical archiving Archive_tusk – atmospheric pressure value, Archive_opadu – amount of atmospheric precipitation, Archive_vologyst – archiving soil moisture values and Archive_temperatyra_1 – archiving temperature value.

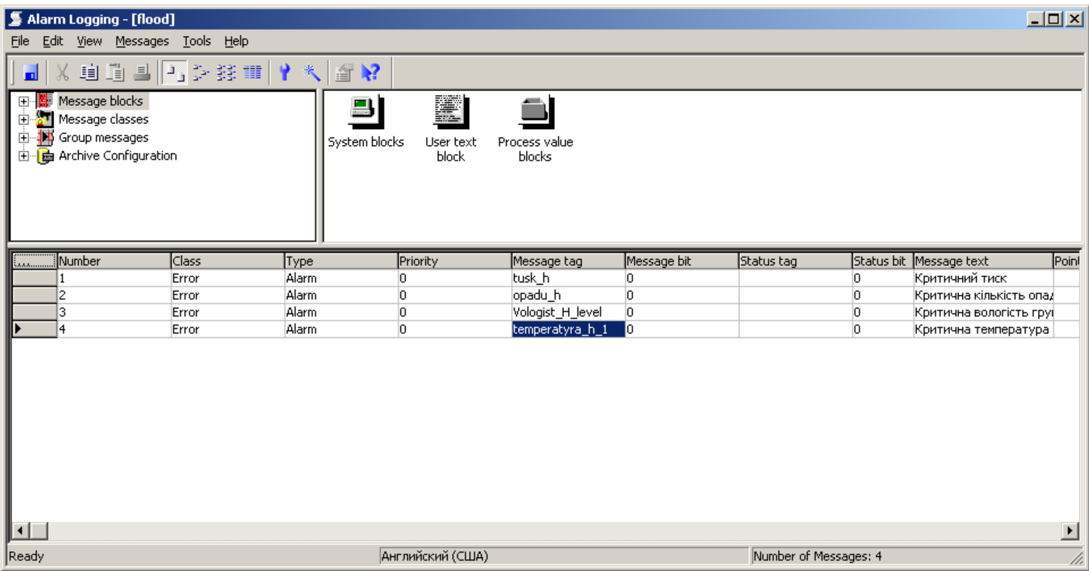

Figure 7. The window for displaying emergency messages

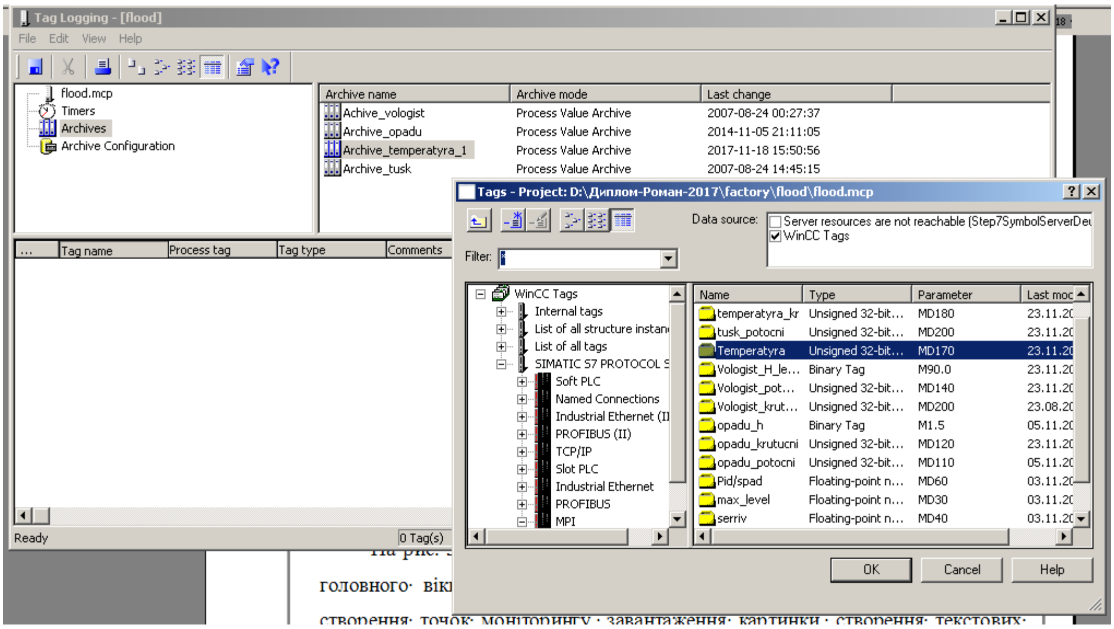

Figure 8. Connecting tags for data archiving

Investigation results. Using the lower level of the automated system for meteorological factors monitoring, the upper level has been designed, i.e.: SCADA WICC [9].

The main investigation results and the process of the main SCADA system window developmentare are shown in Figures 9–12.

The setting of the main window of the meteorological factor monitoring system using Graphics Designer, namely: three meteorological factor monitoring points and the main window of the program is shown in Fig. 9. If necessary, the number of monitoring points can be increased or decreased. The selection of monitoring points (AIBC1) of meteorological data (amount of atmospheric precipitation, air temperature, soil moisture and atmospheric pressure) is determined by the areas adjacent to rivers, which are the most affected by suffusion and mudflows.

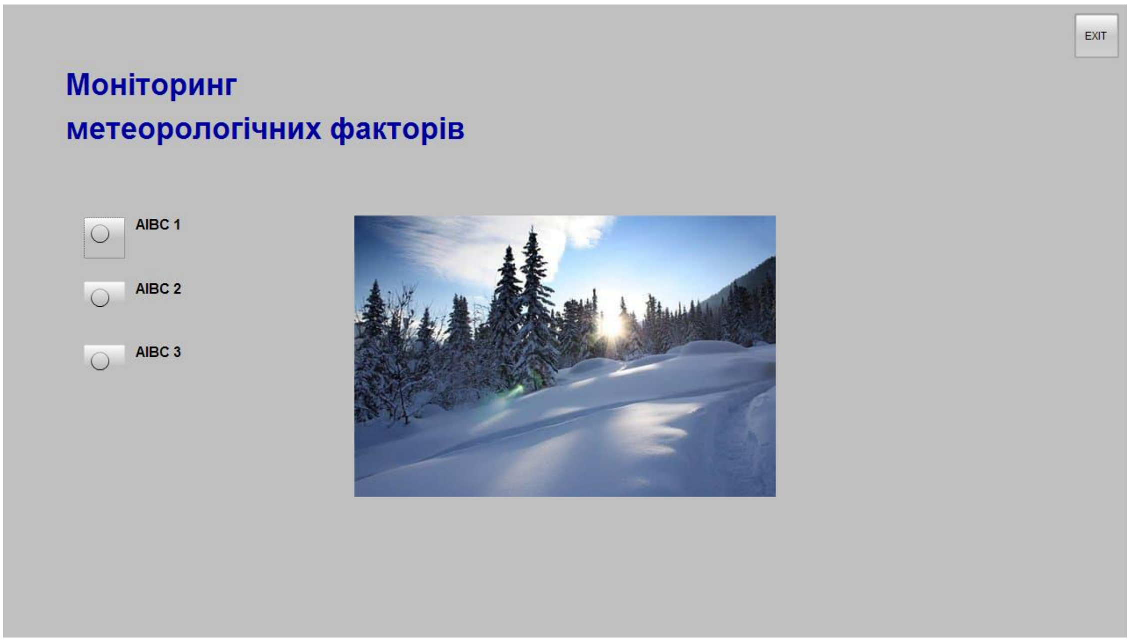

Figure 9. The main window of the meteorological factors monitoring system

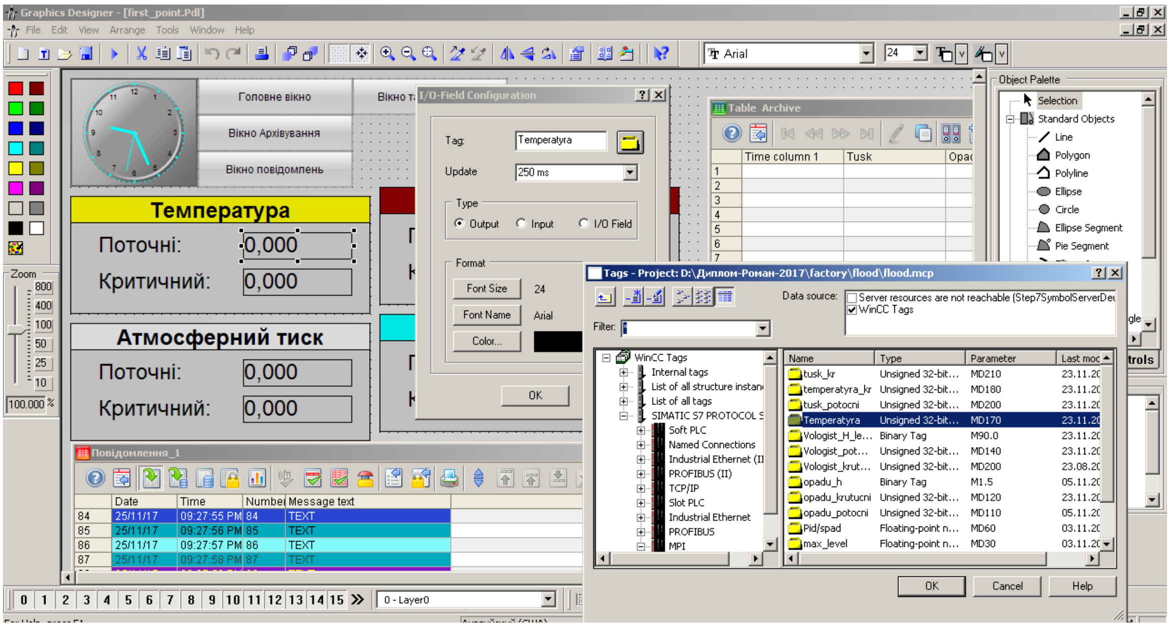

Figure 10. Connecting tags to display current and critical values

The connection of tags to the display of current and critical values of output values is shown in Figure 10. According to the same principle, tags are connected to the archive and output of emergency messages [9, 10]. Figure 11 shows the interface of AIBC1 monitoring point with the following designations: 1 is meteorological factors monitoring, i.e.: the amount of atmospheric precipitation, air temperature, soil moisture and atmospheric pressure; 2 – is numerical archiving of output data; 3 is emergency message output window.

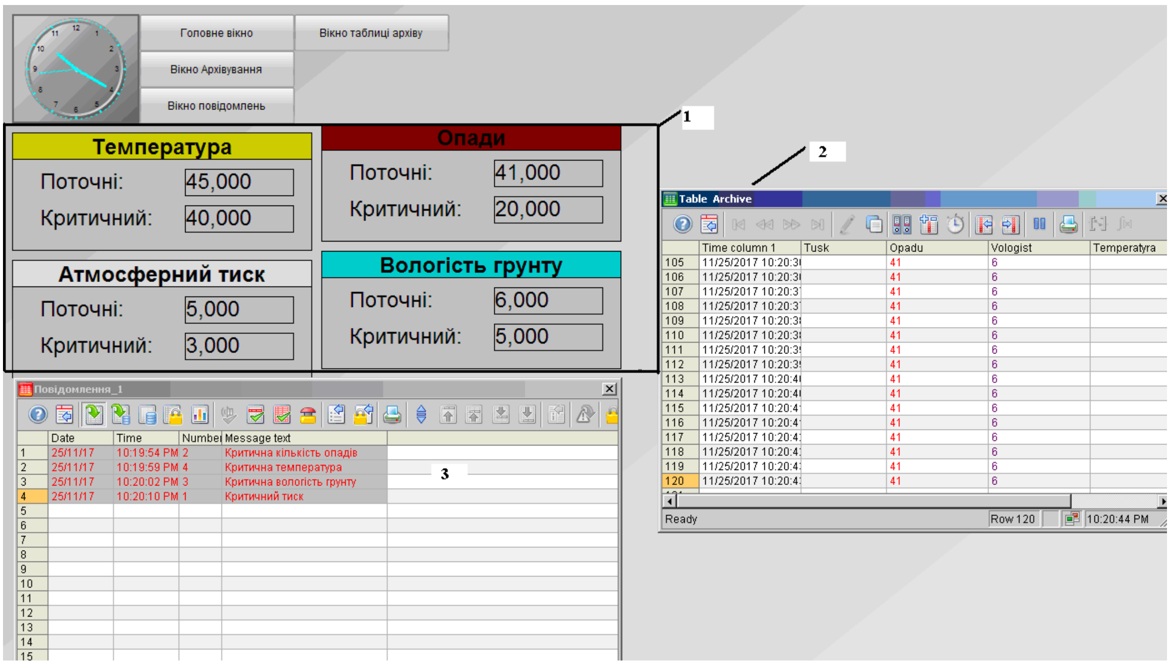

Figure 11. Interface of AIBC1 monitoring point

The simulation window of two-level (lower and upper) system for meteorological factors monitoring (amount of precipitation, soil moisture, atmospheric pressure, and air temperature) is shown in Figure 12.

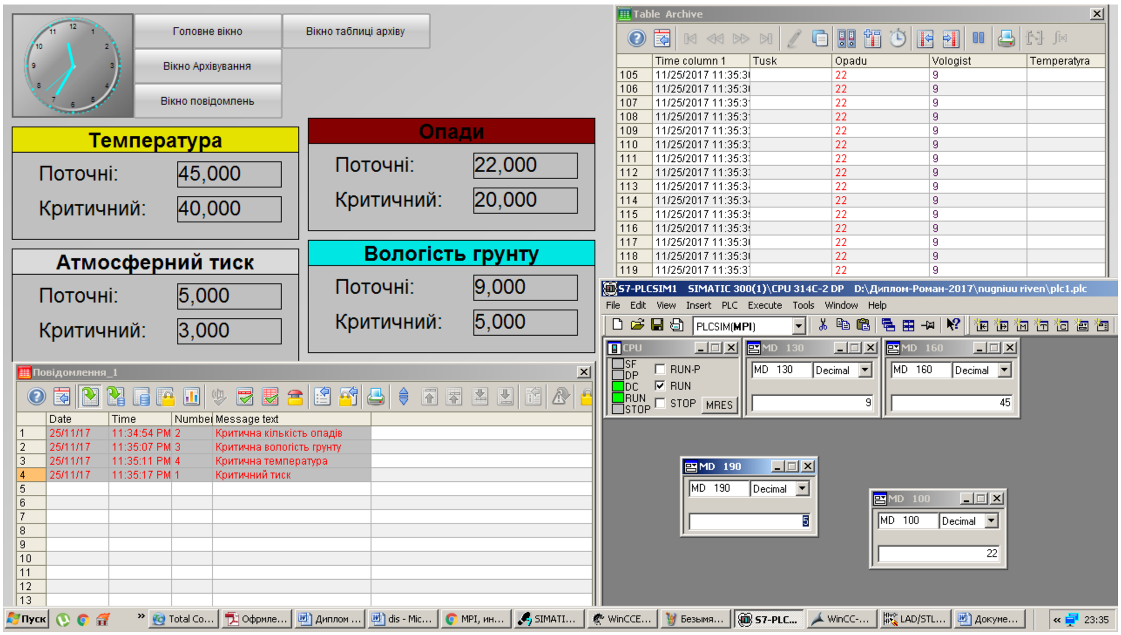

Figure 12. Simulation of the lower and upper levels of the automated system for meteorological factors monitoring

Conclusions. The system for collecting, processing, and transmitting data by means of WinCC v7.0 SP1 software using previously created project in Simatic Manager STEP 7 software environment has been developed.

The main advantages of the proposed and developed automated system for meteorological factors monitoring (amount of atmospheric precipitation, soil moisture, atmospheric pressure and air temperature) compared to the existing ones are: small size of AIBC; implementation of control over initial values; user-friendly interface.

Summarizing the above mentioned, we can conclude that failure to control meteorological factors will result in the occurrence of natural disasters, such as kigh water, floods, mudflows or suffusions and will turn into the most important environmental problem, which at prasent significantly worsens the living conditions of the population whose homes are adjacent to the basins rivers, and have detrimental effect on agricultural lands.

Therefore, we predict that unless immediate and effective measures are taken to reduce the negative and destructive impact of natural disasters these will result in complete destruction of suitable areas for sowing or eviction of people from their homes.

Finally, the development of the automated control system for natural disasters is a priority area of measures to protect the life of population and preserve land that is systematically used agricultural production.

For this purpose, you should:

– plan and build residential areas in compliance with legally defined distance to river basins;

– not pollute water areas with garbage;

– prevent chaotic, unsystematic deforestation;

– use the developed automated system for meteorological factors monitoring, which is characterized by the following main advantages: user-friendly interface, small size (taking into account hardware), and real-time monitoring of output values.

Implementation of each of these measures is not a panacea, but it will reduce the negative impact of natural disasters and improve the living conditions of the population. Implementation of the entire set of measures will make it possible to achieve high effect both in science while developing the proposed system or analogs ones and in everyday life.

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Розроблення Scada системи контролю метеорологічних факторів з метою запобігання природним катаклізмам

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Резюме. *Проаналізовано сучасний стан існуючих автоматизованих систем моніторингу метеорологічних факторів (атмосферний тиск, температура повітря, кількість атмосферних опадів та зволоженість ґрунту), розкрито теоретичні передумови щодо розроблення автоматизованої системи моніторингу метеорологічних факторів. Встановлено, що використання існуючих автоматизованих систем моніторингу метеорологічних факторів не забезпечує оперативного їх контролю, а також не здійснює контроль за зволоженістю водозбору, чим не забезпечується ефективна екологічна безпека довкілля щодо попередження природних катаклізмів (суфозії, селеві потоки). Завданням досліджень було: проаналізувати вплив метеорологічних факторів на навколишнє середовище; проаналізувати сучасний стан автоматизованих систем моніторингу метеорологічних факторів; розробити теоретичні передумови щодо розроблення автоматизованої системи; розробити структурну схему автоматизованої системи моніторингу метеорологічних факторів; розробити автоматизовану систему моніторингу метеорологічних факторів. Розроблена дворівнева автоматизована система представлена нижнім рівнем контролю метеорологічних факторів (атмосферний тиск, температура повітря, кількість атмосферних опадів та зволоженість грунту) здійснюватиметься у програмному середовищі STEP 7, де визначається тип та директорія збереження файлів проекту для розроблювальної системи моніторингу. Станція автоматизації (AS) у STEP 7 на базі контролера S7-300 складатиметься зі: стійки (Rack), яка забезпечує механічні та електричні з'єднання між модулями S7-300; джерела живлення (power supply – PS) для перетворення напруги (змінного струму 120/230 В або постійного струму 24 В) у 5 В і 24 В (постійний струм) у необхідну для живлення S7-300 та CPU (Central Processing Unit – центральний процесор), що виконують програму користувача, взаємодіють з іншими CPU. І верхній рівень – відображення вхідних даних моніторингу на екран, а також подання у вигляді аварійних повідомлень та архівування даних з вказаним часом у програмному середовищі SCADA WINCC.*

Ключові слова: *метеорологічні фактори, моніторинг, дворівнева автоматизована система, екологічна безпека***.**

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