Remote control and monitoring of irrigation process operation and control system architecture

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***Abstract* — This paper reflects the development results of the irrigation processes automating platform for the plantations, which can be very user-friendly to optimize these processes and minimize irrigation costs and therefore serves as a means to become more competitive on the market. It have been carried out the automation of plantation's irrigation process: three irrigation scheduling and control modalities have been proposed and software testing has been carried out to ensure the high reliability of the information and command system and its efficiency with a series of applications for the irrigation monitoring system, which allows the final user to make the necessary totals and decisions.**

***Index Terms* — automating of irrigation processes, irrigation scheduling, remote control.**

I. INTRODUCTION

The Strategy for the Development of Agriculture in Rep. of Moldova provides for the achievement of the nominated goal and the analysis of the agro-food sector, three priorities and a series of measures [13]. **The first priority** provides increasing of the agriculture-food sector competitively form Republic of Moldova (RM), by restructuration and modernization. In the last years the competitively of the agriculture is at the low level depending of some factors. Taking this view as well as taking into account the strategic vision of the sector, it is clear that the Republic of Moldova will increase the competitiveness of agriculture by concentrating on agricultural products with high added value. In this respect, the strategy places a special emphasis on modernizing the sector, improving the level of education and associated systems, and facilitating access to input and output markets. A number of measures must therefore be implemented, such as:

- modernization and restructuring of farms specializing in the production of traditional agricultural products (fruits and vegetables, milk, meat) as well as other competitive agricultural products
- increasing the quality of education, scientific research and extension services in the agro-food sector, including the facilitation of information systems..

The second priority provides ensuring the sustainable management of natural resources. Although the Republic of Moldova has fertile soils and a favorable climate for agricultural production, it faces the many environmental challenges described above. Therefore, a priority for the Republic of Moldova is adapting to climate change at national level and capacity building. Such an approach should include improving farmers' access to new varieties, technologies and information through farmer training; Improving the diffusion of weather forecasts for manufacturers, especially for extreme events; investigate crop reform options to reduce administrative costs and improve accessibility and encourage private sector involvement in climate change adaptation efforts. Improvement of institutional capacities should focus on the identification of drought-resistant varieties and temperatures, more tolerant animal breeds in the current international market for adoption in the Republic of Moldova, as well as the training of agricultural producers in more efficient use of water using advanced irrigation systems and to make use of new weather forecast information. The strategy proposes three measures in this respect:

- investments in irrigation services are also of great importance, along with better access to irrigation infrastructure and modern equipment.
- supporting production technologies and organic products, in order to increase biodiversity and reduce soil erosion while contributing to the conservation of water resources.
- assessments of agricultural producers in promoting and adopting relevant technologies that will help adapt to climate change and supporting a farm insurance fund against natural disasters would increase farmers' confidence and attract investment in new technologies.

Therefore, taking into account the provisions of the strategy, the development of automation tools in the agro-food sector is an activity meant to facilitate these provisions. In the following compartments it will present the automation facilities for irrigation installations, realized within the UNDP project "Autonomous integrated irrigation systems based on wind turbines, small hydro and photovoltaic installations" supported by RoAid the development of the RM, alleviate poverty, improve living conditions and support the transition to democracy [1].

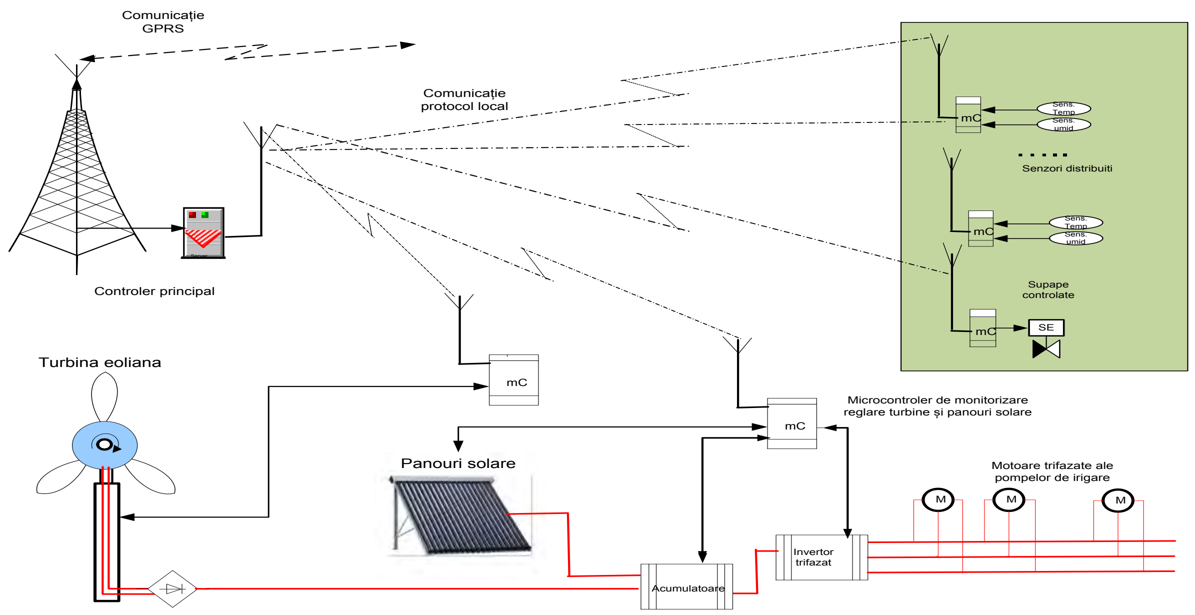

Figure 1. The concept of autonomous drip and sprinkler irrigation integrated with wind turbine and photovoltaic panels.

II. THE CONCEPT OF AUTONOMOUS DRIP AND SPRINKLER IRRIGATION SYSTEMS INTEGRATED WITH WIND TURBINE AND PHOTOVOLTAIC PANELS

At the current stage, although there are very advanced and sophisticated informational technologies and communications, the design of the monitoring and control system is not a trivial problem [2 - 7]. The design of the automated control system for monitoring and optimization to ensure the irrigation processes will be carried out taking into account the following factors: acquisition of climatic data from plantations, application of nutrients and pesticides, herbicides, information processing and automatic control of the irrigation system, such as the monitoring of renewable energy sources. On the other hand, the design of the automated system must take into account the location of renewable plants and resources. In other words, the system has to be territorially distributed and it is reasonable to be hierarchized, considering the various issues that need to be solved.

Taking into account the experience of the most advanced companies in this field as well as their own experience, a three layer hierarchical system has been proposed (fig. 1). The bottom layer is the most sophisticated, nonhomogeneous and dependent and specific of agricultural enterprises. At this level are placed the means of acquiring the climatic data on the plantation field, the means of controlling the valves and pumps with remote control, the means of accelerating the fertilization equipment, as well as the means of monitoring and control of the renewable resources.

The second layer of the system has preponderant communication functions with minimal computing capabilities, decision-making, in other words, a kind of gateway between the lower level and the upper level. The mission of this level is to provide communication coverage with all subsystems at the bottom level and to provide communications to the top level server (server).

Finally, the superior layer of the automation, monitoring and control system for irrigation systems is seen as a typical Internet solution, which will store all information on irrigated plantations as well as the state of the equipment and auxiliary subsystems. On the other hand, it must provide authorized access to users of this system. At the third level (server) will be first remote monitoring of several irrigation systems, groups of stations, including homing. If server monitoring and control node is connected to the Internet, then monitoring stations can be done from any point on the earth.

III. LOW LAYER OF IRRIGATION CONTROL SYSTEM

The control units of the low layer are the core of irrigation stations and wind turbines or solar panels. The architecture of the control units is strictly dependent on the mission of the station should be able to solve a number of operational problems, including:

- Ensuring communication between the turbine and the local station monitoring system;
- Telemetry parameters of turbine control station;
- Control and regulation of power supply station subsystems.

Analyzing the design experience of a range of control units [5 - 8] and given the need to address issues were raised following general requirements to the main control unit of the station:

1. The control unit must be fail proof system, which should in case of failures of hardware to function without consequences or complications, and during repeated concessions, it must be able to perform the most important critical functions of the mission.

Reliability of the command control unit must be not less than 0.9 during a year of activity;

2. All control unit interfaces would be desirable to be duplicated, such as a single interface failure should not lead to full system failure.
3. The control unit must be provided with a memory capacity required for storage of software control, telemetry and payload obtained during the station is not in connection with the monitoring system.
4. The control unit must be able to adapt to other missions without essential changes of the hardware and software.
5. The control unit must be compact and have a reduced power consumption.
6. The control unit must be able to reconfigure its structure with or without reprogramming.

Subsystem for the climatic data acquisition on the plantation field. For any control and monitoring system, including for irrigation installations, data acquisition plays a primary role. For these reasons, it has been decided to build an acquisition subsystem based on an integrated sensor network. It was decided, taking into account the relief and climatic conditions of Rep. Moldova, that the control must be performed by an average performance microcontroller, which will operate autonomously and is monitored and guided by the two more powerful controllers by radio communication at short distances (up to 4-5 km). It was designed and realized the functional diagram and real equipment of integrated sensors and valve control modules for irrigation system. The most important sides of this modules are the autonomous electrical power subsystem with 20W photovoltaic panel, accumulator, remote data acquisition and control by of radio communication. The integrated sensor includes a set of sensors: air humidity and temperature, soil humidity and temperature at 2 levels; rain sensor, luminosity; photovoltaic panel and accumulator voltage (fig. 2).

Given the specialization of microcontroller core functions of low layer for controlling data acquisition, control, regulation and distribution of electricity, telemetry control the thermal station control and a microcontroller auxiliary functions of quality analysis of electricity generated, it is necessary to analyze low consumption devices, which typically are designed for wind generators and irrigation systems. For the integrated sensor module, it has been decided to use the μC ATMega controller, with performance comparable to other controllers, a very low consumption and a lower price.

In the similar mode the valve control module is developed to open/close the valve with solenoid/DC electro-motors and communicate the states of the valves.

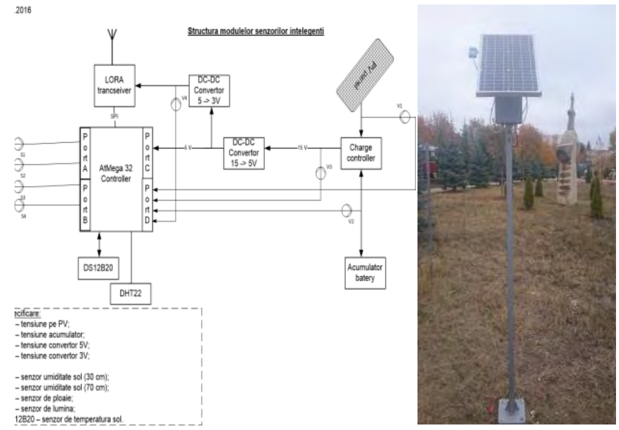

Figure 2. Functional schema and real view of integrated sensors module for irrigation system.

Subsystem for the control and monitoring of the renewable source. The bottom layer of the system also includes the control and monitoring subsystem of renewable sources: wind turbines and photovoltaic plant of irrigation installations. This subsystem has several functions, as the protection of strong wind turbine generator from overheating and monitoring of the rectifier, adjusting the position to optimize power generation station.

There are several variants for this subsystem, depending on which type of wind power and/or photovoltaic panels. If renewable resources have their own subsystem of command, then it only remains to realize the interaction protocol with the second layer controller. In the case of this project a was developed controller for the wind turbines designed and produced at the Technical University.

In the case of photovoltaic panels, the problem is simpler because it is more reasonable to consume the DC power produced by the panels without using DC/AC inverters, leading to significant energy losses. For this, a simple controller is proposed, which measures the voltage/current obtained by the PVs, as well as checking the spindles in case of a short circuit.

The described modules are based on the microcontrollers, it is clear that the software of these modules is the key of success. This developed software includes some components, such as: micro operation system, data acquisition and preliminary processing, control of the actuators and communications modules. The most important are the communications modules, which assure the compatibility of communication protocols with the high level components of the system.

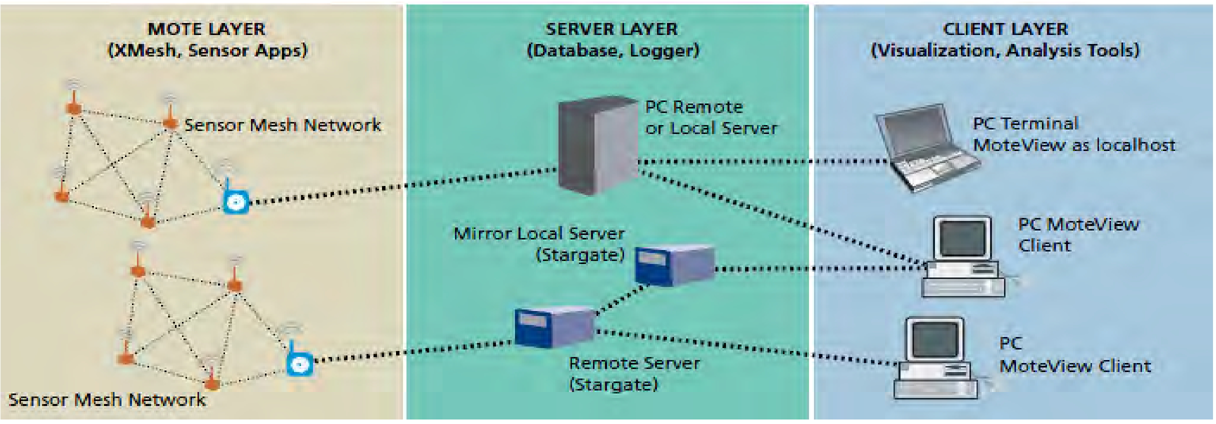

Figure 4. The model of interaction between components of the irrigation system through various networks, including the Internet

Subsystem for the control and monitoring of the pumps. The most reasonable option is to use so-called solar pumps. The specificity of these pumps consists of the use of AC/BLDC electric motors, which consume the turbine or PVs DC current and rotates the pump at various speeds, ensuring certain pressure and flow. Analyzing various solar pumping systems, it has been decided to use the Lorentz solar pumps from Germany, which have the best cost-effective ratio [13]. LORENTZ solar submersible and surface pump systems are designed to efficiently deliver high volumes of water running exclusively on solar power. They are typically used in irrigation projects and for wide area drinking water applications where they reliably meet the most demanding requirements, economically, without pollution and without a grid connection or diesel generator [14]. A typical solar pumping system is composed of a PV generator array, a pump and a solar pump controller. Based on the design philosophy that it is more efficient to store water rather than electricity, there is no energy storing device such as a storage battery in a typical solar pumping system. The PV generator, an aggregation of PV modules connected in series and in parallel, absorbs solar irradiation and converts it into electrical energy, providing power for the whole system. The pump controller controls and adjusts the system operation and adjusts the output frequency in real-time according to the variation of sunlight intensity to realize the maximum power point tracking (MPPT). The LORENTZ pump system consists of a pump end, pump motor and a controller (fig. 3). This modular concept keeps all electronics above ground even for submersible pumps, simplifying servicing and lowering cost.

IV. THE MEDIUM AND HIGHER LAYERS OF IRRIGATION CONTROL SYSTEM

It is proposed a farm plantation **medium layer control module** for irrigation system to coordinate all the processes for irrigation installation and for communication with high level (servers). For this case it was proposed the Raspberry controller with a higher computing performance and low cost and was developed the software for this controller, which include more components for the coordinating the communication between low level modules and the servers.

Interaction between the turbine station controllers, integrated sensors and the monitoring system was proposed to be performed according to a model, for example, as shown in fig. 4, which implies the access of the users of the stations practically from an unlimited distance, which is reasonable by the use of communications and computers, including the Internet.

The problem is simplified if the station controller connects to the network through units with a range greater than the previous one, sufficient to intercept the communications network. For such a case, high-speed and medium-to-high-speed radio communications, there is at the moment a whole range of possibilities and means.

For the communication between the medium and the upper level, we have proposed to use a way, called the GPRS interconnection. In GPRS operations instead, the connection is made directly to the internet as if the GPRS modem was an IP socket network interface. There is no data channel reserved for data sharing between two subscribers, instead the resources are dynamically allocated on demand and the data exchanged is usually packed in TCP/IP, in addition, the maximum transfer speed can be much faster than in GSM CSD mode. This approach has the immediate advantages of designing the GPRS control application Modem directly on the internet, ready to be accessed virtually anywhere in the world at the same productivity on GPRS, in fact, the "billing" of the GPRS connection is based on the amount of data exchanged (number of transferred packets) independently from the moment the connection is active or if these packets need to

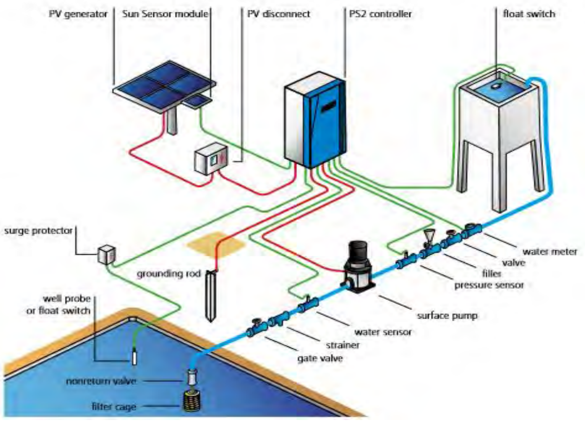

Figure 3. Functional schema of the pump and the controller for irrigation system [13].

be delivered. Therefore, it is possible to leave the control application always logged in and ready to receive / send data on demand, while payment is made only for the really changed data. The disadvantage of the GPRS connection is that the request for control must have its own TCP/IP protocol stack embedded to decode the packets that arrive from GPRS and encode those to be sent over the Internet. This possibility can be seen as a way to get a "virtual" serial connection between the Application Software on the Internet Server computer and the lower level controllers with the GPRS module, regardless of all the software stacks.

The high level layer of irrigation control system. Taking in account the specifics of irrigation systems, it was proposed the architecture of the high level of control and information system based on 2 servers with different destination. First server, named ”background” is organized on ”IOT-technology” (Internet of Things) and have a destination for intensive communication with all local controllers of the irrigation installations. Its advantage is to operate with a lot of row data, without special formatting. But this server is accessible only for the administrator, not for the end-users. The second server, named public server have the destination to store the data about farm plantation, irrigation system and assure a friendly interface for the end-users. The developed database structure of the monitoring system reflects all the necessary components: plantations, plots, irrigation rules, composition and condition of facilities, etc. for the both servers. Conceptually, the structure of data bases on the servers is similar, but logical and physical structure a very different. It was developed a set of applications for data management for public server data base and some applications for graphical viewing of the current data from irrigation system.

V. SCHEDULING, CONTROL AND MONITORING REPORTS OF THE PLANTATIONS IRRIGATION PROCESS

The analysis of several plant irrigation control systems has various approaches: from complete automation to various mixed modes. These approaches aim to relieve the user of effort and other worries about irrigation of plantations, but as full automation is mentioned, although it saves time on the user, they are not always the most effective. The reason for decreasing efficiency can be to ignore factors in the process of optimization, to create a simple model to be well understood by the user.

As a result of this, we have decided to implement several approaches to scheduling and controlling the irrigation process, considering that the users are very different: some have only some agronomic knowledge, others are very familiar with agronomic and irrigation issues, they know just as well soil and plant specifics. For these reasons, it is proposed the following approaches to the irrigation process scheduling and control problem:

- Automated scheduling and closed loop control/regulation;
-Semi-automatic scheduling and open loop control/regulation (case A);
- Manual scheduling and open loop control/regulation (case B).

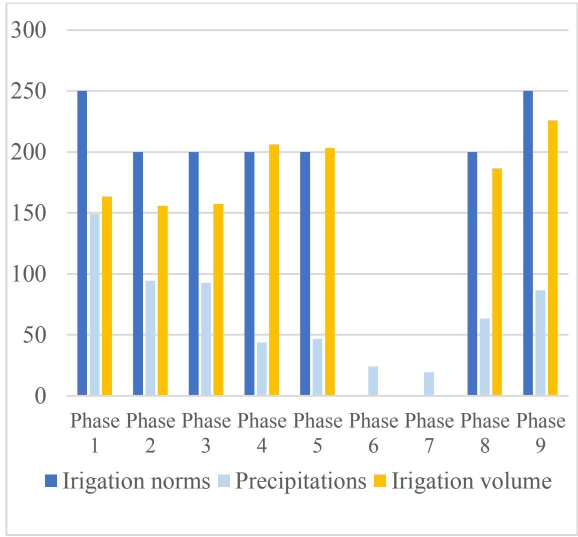

Figure 6. Example of report diagram about irrigation norms, precipitations and irrigation volumes for the each phase of plant development

Typically, two general types of controllers are used for control in irrigation systems: open loop control and closed loop control. The difference between these is that the closed loop will have feedback from the sensors to make automated decisions and apply them to the irrigation system. On the other hand, open loop systems apply a timed irrigation action, pre-set by the operator. Each of them has their advantages and disadvantages. The first ensures pure automatic operation and ensures optimal water consumption, the second requires human factor intervention and responsibility rests with it. In the proposed system, these types of control are described, which are described below, which will enable the irrigation to be implemented most appropriately in the consumer's view.

Automated scheduling and closed loop control / regulation. The idea of this approach is to plan the process on the basis of normative data of irrigation of concrete plantations on certain soils and with the possibility of adjustments of these norms, and the control/regulation process is done with closed loop based on data acquired from intelligent

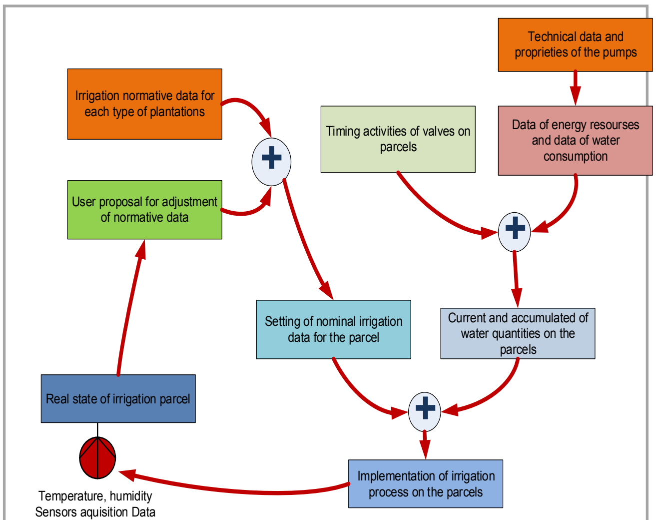

Figure 5. Semiautomatic planning of irrigation processes (open loop, case A).

humidity sensors, temperature on the respectively parcels.

In closed loop control systems, the control circuit requires the acquisition of environmental data (soil humidity, radiation, wind speed, etc.), but also from the system (parameters such as pressure, flow, etc.) by using multiple sensors - feedback loop, closed loop for the decision block. The user establishes only a control strategy, and the system takes this information and determines the detail decisions regarding the irrigation time and volume, actions that are performed based on the data received from the sensors. Reverse feedback and system control are performed continuously, automatically.

The thrust of this approach is to release the user from certain tasks, complete automation, and save time for the user. On the other hand, this approach will take account of added rainfall without user intervention. The disadvantages of this approach are the need for sensors on each controlled parcels. On the other hand, if the parcel is larger, the effect of non-uniform of the irrigation of the parcel may occur.

Semi-automatic scheduling and open loop control/ regulation (case A). The idea of these approaches is more complicated and consists in scheduling the process both on the normative data of irrigation of the concrete plantations on certain soils and with the need to adjust these norms, taking into account several factors: real data from the sensors on the plantation, the properties of the actual amount of rainfall in the period, and the adjustment process is performed with an open loop not based on the data acquired from the intelligent humidity sensors, the temperature on the respective parcel, but on the basis of the quantity of water delivered on each parcels (fig. 5). In this case, the basic control parameters are directed to how often and how much irrigation is applied to controllers that use timers/clock to turn irrigation on and off by applying a given volume. Advantages. Open loop control systems have the advantages of being low cost, easily accessible and many device variations are manufactured with varying degrees of flexibility in relation to the number of parcels and do not require sensors on each parcel but a limited number plantation. Disadvantages. These systems have great drawbacks - they do not automatically respond to changing conditions in the environment and require frequent reset by the operator to achieve a high level of irrigation efficiency. As a result, efficiency is dependent on operator / user experience.

Manual scheduling and open loop control / regulation (case B). The idea of these approaches is very simple and consists in scheduling the process not on the basis of normative data of irrigation of the concrete plantations on certain soils and with the need to adjust these norms taking into account several factors: real data from the sensors on the plantation, the real properties of the soil, the amount of precipitation in the intervals, but only the user experience and the adjustment process is performed with an open loop not based on the data acquired from the intelligent humidity sensors, the temperature on the respective parcel or the quantity of water delivered on each parcel, but on the basis of the irrigation time at each parcels.

Advantages. Open loop control systems have the advantages of being low cost, easily accessible, and requiring no sensors on each plot, but a limited number on plantation or even lack thereof. Disadvantages. This approach has a big disadvantage (as in case A) - they do not automatically respond to changing conditions in the environment and require frequent reset by the operator to achieve a high level of irrigation efficiency.

As a result, efficiency is fully dependent on operator/user experience. Achieving these three approaches will enable the user to apply that approach to that plantation, which is considered more effective.

Any system for monitoring various processes, including plantation irrigation, requires totalizing means/tools, reporting on current and cumulative outcomes. Therefore, a series of applications have been developed for the irrigation monitoring system, which allows the final user to make the necessary sums and conclusions. It is presented a series of such reports: the user can visualize the irrigation water consumption on the selected parcel during certain stages of planting development or throughout the season as compared to the irrigation rules and the precipitations (fig. 6), report about portions of irrigation norms, precipitations and irrigation volumes for the some phase of plant development, report diagram about portions of irrigation norms, precipitations and irrigation volumes for all the phase of plant development, also report diagram about irrigation norms, precipitations and irrigation volumes for the each phase of plant development, etc.

VI. CONCLUSION

Current information and communications technologies serve as a platform for automating of the irrigation processes for the plantations, which can be very user-friendly to optimize these processes and minimize irrigation costs and therefore serves as a means to become more competitive on the market . The developed the hardware of acquisition, processing and communication for the remote control and management of irrigation installation and the realized software of the low and medium layers provides the remote control. The proposed architecture, software structure for the background and public servers can store all the data about irrigation processes. It have been carried out on the automation of plantation's irrigation process: three irrigation scheduling and control modalities have been proposed and software testing has been carried out to ensure the high reliability of the information and command system and efficiency with a series of applications for the irrigation monitoring system, which allows the final user to make the necessary totals and conclusions.

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