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AUTOMATED IRRIGATION SYSTEM FOR AN EXPERIMENTAL AGRICULTURAL FARM

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ABSTRACT

In the present work, an automated and specialized control device is proposed for an experimental farm's irrigation system to control the water supply and make it more efficient appropriately. An analysis of the operating conditions in the experimental farm's irrigation system is carried out before being automated. The different types of irrigation, the techniques to be used, the variables necessary for applying these techniques, and the machinery and tools used for irrigation are analyzed to achieve this work. As a result, a specialized device for irrigation control is implemented with multiple functions that respond to the application area's needs. This device is robust, stable, and capable of expanding its capacity to adapt to the applied field, as well as saving resources and achieving greater effectiveness in terms of the irrigation process.

Keywords: automation, controller, irrigation system, experimental farm.

1. INTRODUCTION

An experimental agricultural farm is used to improve and develop irrigation techniques (Santos *et al.,* 2010). It also is used to measure the impact of agriculture in all areas that affect society, such as the environment in which it is applied, the efficiency in the resources management, the productivity obtained, and the desired cost/benefit ratio. It is also used in general the contribution to society as a result of the work carried out according to the studies and regulations established by the Ministry of Agriculture of Colombia (Condiza *et al*., 1998).

The supply of water and nutrients, the geography of the area, and the weather are important for the farmer; therefore, an appropriate system for acquiring information related to the variables is necessary. This information must analyze agricultural tasks' management and administration to provide reliable and relevant data for the agricultural community (Soler, 2011). In this way, the integration from data obtained with the specialists' decision-making is crucial because the producer's active participation in the irrigation design planning and establishment is essential for land productivity (Carrazón, 2007). However, the farmer's experience determines some actions that the crop requires due to his knowledge and management in the agricultural activity.

An irrigation area has unique features that must be considered by the controlling device to fulfill the primary function of supplying water and nutrients to the planting field. Some features that must be considered to implement an autonomous irrigation system are the water source, the land's topography, the climatic factors, the soil chemical composition, and the land size to be irrigated (Soler, 2011).

The structural needs, such as irrigation systems design, the irrigation methods, the number of irrigation sectors, and the mechanisms of action in the pipeline are the physical characteristics to consider when integrating the area working with the system that governs the administration of the tasks to be performed. Additionally, it is crucial to study and determine the components external to the equipment, such as sensors, contactors, and the different types and standards handled by the solenoid valves corresponding to the final system output (Wahl, 2013).

Significant works have been made in the automation of irrigation systems, in such a way that a state-of-the-art review for control strategies used for the distribution of water in irrigation systems, aimed at increasing the operability of these systems is carried out (Hernández-López et al., 2020). This paper proposes an automated and specialized control device for the irrigation system to properly control the water supply and save on resources more efficiently and less complicatedly.

2. MATERIALS AND METHODS

2.1 The Experimental Agricultural Farm

This work is implemented in an experimental agricultural farm with an elevation of 450 meters above sea level, with an approximate area of 310,512.25 m^2, of which 84,880.64 m^2 belong to the sprinkler irrigation area (Izquierdo Bautista *et al*., 2009). Sprinkler irrigation is distributed in 9 sectors with their respective irrigation supply valves, as presented in Table-1.

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Table-1. Distribution of valves by irrigation zones.

Irrigation zone	Number of supply valves
Mango	2
Orange	1
Nursery	1
Vegetable plot	1
Yatropha	1
Fixed sprinkler	1
Drip	2
Moringa micro-spray	1
Moringa spray	1

The remaining field is irrigated by gravity, which is distributed in sectors that do not have valves because they do not have a pipeline; in other words, the irrigation process is carried made channels (characteristic of gravity irrigation). The device that oversees supplying the water to the channel from which the gravity irrigation seeding sectors are fed is a reference pump 3 Mot.1 LA3 164-2 YB70 brand Siemens, shown in Figure-1.

Figure-1. Farm gravity irrigation pump.

The mentioned pumping unit is characterized by having a flow capacity of 860 GPM (Gallons per minute), a total dynamic head of 65m, and three filters: a 100GPM sand filter, a 150GPM ring filter, and a 150GPM mesh filter.

2.2 Design Considerations

An operating conditions analysis of the irrigation system in the experimental farm is carried out before being automated, and the following conditions are found that must be considered to automate the system:

During filter washing, the pressure should not exceed 120 psi; and the sprinkler pump has a total capacity of a maximum of 5 open valves. The sump water is not enough to supply a long period of irrigation. The pump house is approximately 200 m from the main house, and finally that they plan to open new irrigation sectors in the future.

Once the information on the experimental farm conditions has been analyzed before being automated, the proposed devices are defined below.

2.2.1 Pump motors to control

The controller must assist the starting of two pump motors, one for gravity irrigation and the other assigned to sprinkler irrigation. The ignition of the motors leads to the previous priming so that the pump does not decompensate. Therefore, the controller before ignition must generate a dead time while the priming activity is carried out, controlling two electro valves.

2.2.2 Valves to be control

The system must control a total of 14 solenoid valves (9 for the sprinkler irrigation sectors, 3 for the filter washing system, and 2 for the priming system) and support some more due to possible expansions or the creation of new one's future irrigation sectors. It is decided that the controller will have 20 outputs for the sprinkler irrigation sectors, three additional outputs to control the filter washing system, and two more for the priming system for a total of 25 solenoid valves.

2.2.3 Variables to measure

At present, there are several types of transducers dedicated to measuring several variables directly or indirectly and with specific response curves depending on the transducer element used. Regarding the field variables to be measured, the controller must have the ability to connect to any sensor according to standard technical standards. The specialist in agricultural data interpretation may need many variables such as PH, humidity, levels of oxygen, light, etc., to diagnose and assess in the best way the crop conditions.

2.2.4 Communication with peripherals

The controller is divided into two electronic cards due to the distances between elements and functions that it must fulfill. The first one is the main board located in the main house, and which must control the sprinkler irrigation solenoid valves and the additional solenoid valves for future extensions. It must also control the programming of watering cycles, initial controller settings, and the acquisition of variables. The second card is located in the pumping house, approximately 250 meters from the main card. It performs the functions of starting the pumps, priming them, and washing the sprinkler irrigation system's filter. communication between the main card and the secondary card is done through wireless signals considering the cost-benefit ratio at the time of implementing the project, due to the number of functions to be performed, while the main board communication with each one of the solenoid valves in the field is carried out using copper wires.

2.2.5 Irrigation cycles

Depending on the soil characteristics, the environment temperature, the moisture, and the techniques used, the irrigation cycles can vary from several times per day in an irrigation sector to 1 time every n-days per sector. These same irrigation cycles are the activity cycles of a solenoid valve. In gravity irrigation, the controller is arranged to operate one cycle every minute. However, technically it is impossible due to the system design due to the motor-pump priming before working, up to 1 time every n-days. The limitation of the controller in the operation field of gravity irrigation is 28 irrigation events (understood as an event, the motor-pump switch-on, and subsequent switch-off) being sufficient if it is considered that in general in the experimental farm, the number of irrigation events per day does not exceed two times.

3. RESULTS AND DISCUSSIONS

3.1 Implemented Device

The control system turns on and off two pump motors, one for gravity irrigation and the other for sprinkler irrigation, a filtering system whose function is to eliminate the residues in the fluid circulating through the pipeline. This pipe must be cleaned periodically, a procedure that is also performed by the designed controller. In addition to the controlled pumps, the system opens and closes the solenoid valves that establish the irrigation of the farm's different sectors. Likewise, the device has 10 data acquisition channels which can be configured to handle two different standards used by the transducers according to the information transmission signal levels, corresponding to the standard 4 to 20 mA or 0. at 5 volts.

The result obtained is a controller device shown in Figure-2, used for irrigation control with multiple functions obtained by analyzing the needs presented by the application area, that is, the experimental farm. This device is robust, stable, and expandable for the applied field.

Figure-2. Implemented controller device.

To better understand the implemented device, Table-2 shows the sample of the device's technical specifications.

Table-2. Technical specifications of the implemented controller device.

Features	Description
Number of valves to control	20 sprinkler irrigation solenoid valves, 3 for the priming system, 3 for the filter cleaning system
Number of analog channels	10 data acquisition channels
Inputs	Standard 4-20 mA and 0-5 volts
Outputs	24 VAC / 12 VAC at 250 mA
Number of pumps to control	1 gravity irrigation pump and 1 sprinkler irrigation pump
Consumed power	Maximum power consumed = 122.5 watts
Security report	Activities copy carried out by the controller in a micro SD generated in a .txt file
Hybrid communication system	Communication with the solenoid valves via copper wiring and communication with the pump house by radiofrequency

The user interface programming considers human error situations in the configuration of the controller irrigation activities, such as:

It sends possible erroneous data corresponding to the programmed itinerary and the solenoid valves that must be activated in each of the shifts in use. This situation is prevented by an insurance system that prevents user interaction with any set of controls that should not be used depending on the system's mode (automatic programming, filter wash, manual programming, delete event, clear table). Also, an internal system is responsible for calculating the appropriate values for the actuated valves consumption and the work times to execute the irrigation system filter washing.

The possible modification of the system work schedule by people outside this work or errors by the operators in which the calendar and the active irrigation sectors configured are altered. This situation is prevented by adding a verification system integrated into the controller, which links the device memory with the software application to visualize all the information programmed in the system. Then a txt file is generated, which contains the itinerary to be executed by the controller and a historical report that allows verifying possible executions affected by unforeseen changes.

3.2 Irrigation Controller Hardware

The hardware-level controller is composed of 4 electronic cards, as shown in Figure-3. The main card has two 18f4550 microcontrollers, a 24LC512 EEPROM memory, a DS1307 digital clock, and a 2GB micro-SD memory with their respective configurations. This card is in charge of receiving the configurations made in the graphical user interface; it stores the EEPROM memory's irrigation routines and activates them depending on the predetermined time.

This card also reads and stores the variables from the transducer coupling card, activates and deactivates the solenoid valves, and keeps a log of the activities carried out by the controller stored in the micro-SD memory through a .txt file with the time and date executed.

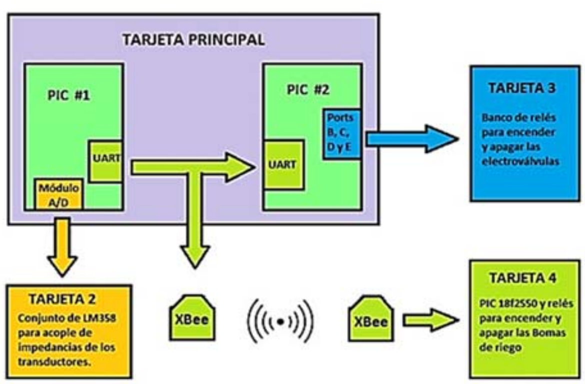

Figure-3. Connections between the cards that make up the controller.

Electronic card number 2 is responsible for coupling the transducers to the inputs of the analog-digital converter module of the main card. The signals are read according to a specific format to achieve an exact reading. An LM358 integrated circuit is used to perform the impedance matching between the transducers and the module inputs. The LM358 is in unity gain configuration, and a knob switch is used to switch between the two data signal transmission formats supported by the controller, which are 4 to 20 mA and 0 to 5 volts.

The card in charge of activating and deactivating the solenoid valves is electronic card number 3, which comprises 20 relays. Each relay assists a specific solenoid valve. The information is received by a 22-pin connector, linked to a data bus connection from the other end to the main card, specifically to ports B, C, D, and E of the microcontroller number 2 in the mainboard. The data bus has 22 pins, 20 for activating the relays and 2 for common ground.

The distance between the pump house and the distribution ground for the solenoid valves is approximately 500 meters. Therefore, as specified in the previous section, an intermediate site is sought between the two to locate the control center. This site is located near the main house, approximately 250 meters from the pump house, where the agricultural machinery is kept. This situation is due to the transmission between the controller and the irrigation pumps' activation by wireless means. It is necessary to receive and process the XBee transceiver module's signal to carry out this task, connected to microcontroller number 1 of the main electronic card. This information is received by electronic card number 4, which is composed of another XBee transceiver module connected to a 18F2550 microcontroller through the UART (Universal Asynchronous Receiver Transmitter) communication protocol, and six relays in charge of activating and deactivating the irrigation pumps, filter washing, and priming of the sprinkler system pump.

The electric circuit power in the pumps used for irrigation is shown in Figure-4. Since the relays used to activate the irrigation pumps do not support the current necessary for the start-up and operation of said motors, it used a power stage stored in the pumping house facilities. Industrial-type relays carry out the control of the power supply to the pump motors called electrical contactors.

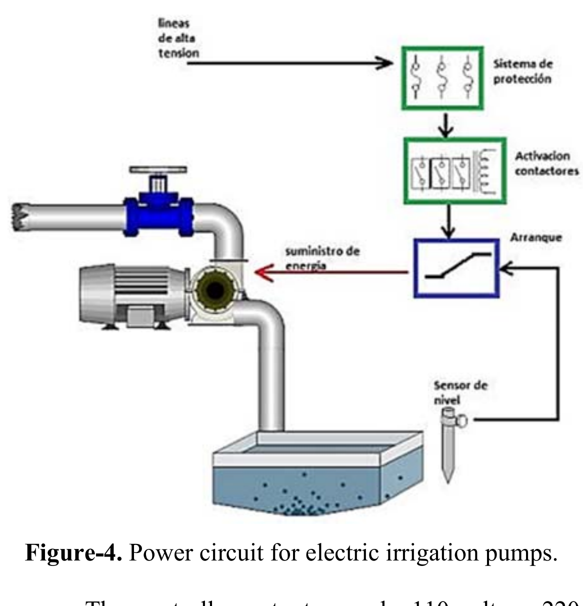

Figure-4. Power circuit for electric irrigation pumps.

The controller outputs supply 110-volt or 220-volt levels depending on the relay capacity, the source supplying the power, and the electrical contactor's activation levels. These outputs feed the electrical contactor coils, which activate the electromagnet and

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move the moving mechanism to join the contacts at each end. One side is connected to the high voltage lines or, failing that, a transformer, and the other terminals are connected to the electric pump to generate the closing of the circuit and the device turning on.

3.3 Irrigation Controller Software

The program configures the controller is divided into four fundamental parts: each located in a tab to organize the activities to be carried out by the controller and achieve a user-friendly graphical interface. The first tab is called "Office" and oversees initializing the controller clock and generating a desired programming report in a .doc file. This tab has the objective of serving as a support for the controller's configurations and bringing the irrigation information in an organized and automatic way for later analysis (Figure-5).

Figure-5. Tab 1 "Office".

The second tab is called "Sprinkler Irrigation" and is shown in Figure-6. This tab is used to program the events and irrigation shifts for the sector irrigated by the sprinkler method. This tab has multiple functions. The following stand out filter washing, irrigation times within an event to switch irrigation sectors, elimination of a complete irrigation event, and deleting all programmed irrigation activities. It is possible to observe through the "fill table" button in real-time which activities or irrigation shifts are stored in the controller's memory and, therefore, will be executed. The application has time controls and increment boxes in hours and minutes. To program the end and start of the event and shift. The filter wash and the valves to be activated have an individual space within the tab to organize the information and facilitate user management.

Figure-6. Tab 2 "Sprinkler irrigation".

The tab "Irrigation by gravity" is divided into two significant parts. The first is this tab's characteristic function, which is in charge of scheduling 28 irrigation events that are not more complex, merely a date and event start time and a watering event end date and time. In addition to the previous function, this part of the tab has the correction of an event in case of lost total irrigation events (equivalent to delete or set zero the table that symbolizes the registers or programming spaces of gravity irrigation). The second part of the irrigation by gravity tab oversees reading the memory registers where the transducer reading data have been stored, deleting the registers, and initializing the time to save the information or the desired values' variables. (Figure-7).

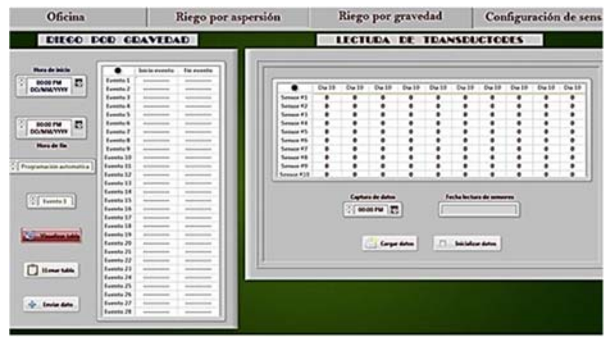

Figure-7. Tab 3 "Irrigation by gravity".

Tab number 4 provides the user with the necessary tools to establish the equations of each of the ten acquisition channels for variables to process the data. The transducers' response curves modeling is made using the input variables, output variables, and the equations that describe said response curves; Furthermore, the data reception format of 4 to 20 mA and 0 to 5 Volts can select for each channel (Figure-8).

Figure-8. Tab 4 "Sensing configuration".

3.4 Data Acquisition Channels

A card containing an LM358 circuit is used to connect the transducers' signal with the analog-digital conversion pins of the microcontroller used for data acquisition. Each op-amp in-unit follower configuration is used to match the signal from a data acquisition input to the A / D (Analog / Digital) microcontroller input.

The unitary follower configuration is used for important reasons such as output voltage equal to the input voltage (Vout = Vin) and high input resistance. This feature is useful when converting current to voltage through a precision resistor (4-20 mA at 0-5 Volts). It is also possible to eliminate loading effects due to an operational amplifier's general characteristics, such as high input impedance (MΩ) and low output impedance. In this way, it is possible to adapt the impedances of different stages, which according to the characteristics described above, are useful for reading voltage levels, reducing errors in load resistance readings (Coughlin and Driscoll, 1993).

4. CONCLUSIONS

The implemented controller device meets the specific installation conditions required in the experimental farm infrastructure used for this project. This system is divided into two interconnected parts that fulfill different irrigation management functions; the first part manages the sensors stage and the irrigation sectors' activation, while the other part oversees the pumps activation and the filter washing.

The graphical interface developed allows the user to design and program the various irrigation events necessary in the experimental farm in a versatile and friendly way since the distribution of all the information is integrated into a single table for viewing. Also, it allows you to send and receive programmed data in real-time so that they can be consulted and/or modified by the administrator at any time. Finally, it can generate a report of the information in a standard format created in a text file for printing. It can be used as a reference to the programmed irrigation schedule.

The control and supervision system enables the future possibility of new expansions if necessary. The internal configuration that makes up the designed software allows a relatively simple way to integrate new irrigation sectors, events, and shifts to be programmed and expand the maximum number of valves to activate simultaneously. On the other hand, the hardware that makes up the controller allows cards destined to control new sectors supported by the serial communication used.

The purpose of the system is to control and manage irrigation and provide academics researchers with a versatile tool to show the system used in operating and clarify the function that each of the variables in charge of this type of control.

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