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A CASE-STUDY VISION

Remote crops: case study of critical variables

Cultivos a distancia: estudio de caso de variables críticas

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Abstract

At present, the improvement of industrial-type processes aims at having products that meet the highest standards, optimizing resources and responding promptly to any developments that affect their results. In this article, a case of a system of supervision of a remote crop type plant, monitored by means of SCADA type platforms in a workstation distant from the physical location is introduced, with automation equipment that allows to display and adjust variables that are critical for the process, such as pressure, operation of irrigation water pump, failure states or actuator operation (at request of end customer), among others (not limited to these). The information generated is sent through IoT (Internet of Things-Internet of Things) technologies to a workstation where an end user can change or affect the variables of that plant, and thus,

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take actions to mitigate affectations in the quality of the final product, also leaving improvement plans for future implementations of similar characteristics.

Keywords: Environments, IoT, Plant, Protocols, Remote, Supervision, VFD.

Resumen

En la actualidad, la mejora de los procesos de tipo industrial tiene como objetivo disponer de productos que cumplan con los más altos estándares, optimizando los recursos y respondiendo con prontitud a cualquier novedad que afecte a sus resultados. En este artículo se presenta un caso de un sistema de supervisión de una planta de tipo de cultivo a distancia, monitorizado mediante plataformas de tipo SCADA en una estación de trabajo distante de la ubicación física, con equipos de automatización que permiten visualizar y ajustar variables que son críticas para el proceso, como la presión, el funcionamiento de la bomba de agua de riego, los estados de avería o el funcionamiento de los actuadores (a petición del cliente final), entre otros (no limitados a estos). La información generada es enviada a través de tecnologías IoT (Internet of Things-Internet de las Cosas) a una estación de trabajo donde un usuario final puede cambiar o afectar las variables de esa planta, y así, tomar acciones para mitigar afectaciones en la calidad del producto final, dejando además planes de mejora para futuras implementaciones de similares características.

Palabras clave: Entornos, IoT, Planta, Protocolos, Remoto, Supervisión, VFD.

1. Introduction

One of the main interests of the full-scale industry is to provide products that meet high quality standards with the least use of resources and the maximum possible utility in all sectors of the modern economy; to achieve this end, numerous monitoring and follow-up techniques have been developed during the manufacturing and extraction or obtaining of industrial products; A classic example is given in a crop, where the priority is to constantly irrigate the main yields, avoiding in a prior way losses of raw material, time and money.

Of the methods commonly used in manufacturing is the SCADA system (Supervisory Control And Data Acquisition), which is defined by Daneels and Salter [1], as an architecture of control systems articulated with software that is installed in a unit of control, which interacts with elements of “distributed control” located in the plant to be intervened (crops in this case) [2], and which allows information on critical variables, their status, errors, and actions to be taken almost immediately in case these are deviated from their normal work values.

Colombia is a country with a large plant biodiversity, where the increasing importance is to optimize the entire production process, and that is where becomes relevant the IoT (Internet of Things) or IoT, which is the natural evolution of SCADA, brought by the rise of connectivity, the rapidity of the growth of the internet, the need to have the greatest amount of information available on the processes and the practicality of sending and having such information hosted in a cloud computing, [3], [4] which have the following characteristics: the long distance that can separate the end user from its location, the difficult geographical access, the complexity of the cultivation to run traditional field buses, and the need for scalability to increase the variables to be monitored and have more data to make decisions or carry indicators.

The idea of IoT emerged a few decades ago in the history of modern industry, and dates back to 1999 derived from the conception generated by Kevin Ashton while working for Procter & Gamble®, who coined the term to make known that each manufactured object and made available to customers can be tracked and coded for the purpose of quantifying their characteristics; it is "empowering computers to sense the world for themselves" [5]

Taking into account the above, the results of a case developed locally applied to a remote sugarcane crop are disclosed. It is said to be remote since its geographical location is hundreds of kilometers away from where the end user is located, who can take corrective actions that allow adjusting possible deviations in the critical variables that lead to results below the established standard; It can be applied to other types of crops throughout the national geography, presenting its characteristics during its implementation.

The presented design consists of 3 components: the sensor system at field, the information acquisition node (implemented in a Programmable Logic Controller, PLC) and the support of web connectivity. There are already implemented industrial solutions in the market [6] and other discrete [7], which exemplify that in the field of Agro-Tech there is a great opportunity for improvement that can be taken advantage of in our emerging markets.

2. Methodology

2.1 Of the crop and its characteristics

In Colombia there is an extension of 1,141,748 km2, and 928,660 km2 of maritime domain, but there are few extensions that are used for cultivation: 9.9% of the territory's surface is suitable for exclusively agricultural work and of this percentage only 3,955,000 ha (approx. 3.5% of the total surface area of the country) benefit is taken [8], so it is relevant to know the critical variables that affect the development of a crop to have productions that comply with the Quality standards to meet the needs of all customers. An example of industrial cultivation of the national economy is presented in Figure 1: sugar cane, its production in tons and the area of cultivation destined in the departments that produce it.

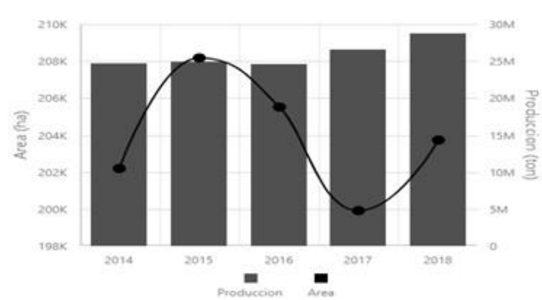

Figure 1. Harvested area and sugarcane production in Colombia. Source: AGRONET [9]

This is mentioned because sugarcane was the crop selected for the experience, due to the conditions of large volume of irrigation required, as well as the extensions of plants to be irrigated and the systems used for this work: only in 2017 the departments that produce Sugarcane generated 2.2 million tons of sugar from 24.38 million tons of cane, 367 million liters of bioethanol were also obtained for use in the gasoline mixing with E8 ratio (92% of gasoline, 8% ethanol) [10]; It should be noted that it is also possible to apply this development for plantations of other types of fruits or vegetables. Although Colombia is a country with great agricultural potential as seen in the results obtained by M. Manchego in [8], there is an important opportunity for improvement to reach the level of implementation of countries with a strong agro-industrial economy, such as those located in Asia, which allow developing beneficial solutions for national agro-tech [11].

2.2. Scheme of Implementation

The general architecture used for agro-industrial applications is shown in Figure 2.

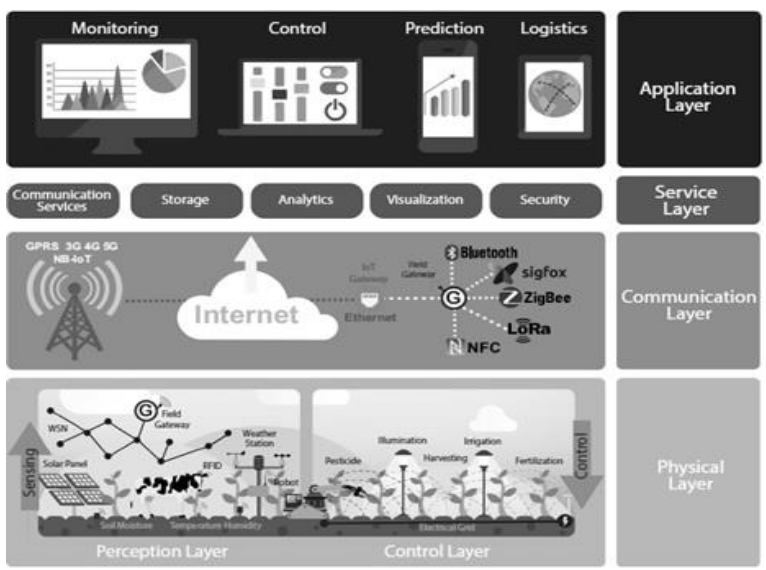

Figure 2. Network architecture for agro-tech applications. Source: J. Talavera et al. [11] pp.

The physical layer corresponds to the sugarcane crop, and the critical variables monitored are related to its irrigation. The communication layer is established with a cloud IoT platform to allow remote interaction; The service layer is embedded in the application itself, through the PLC + dashboard set that presents the variables.

The solution scheme, from the point of view of conformation, consists of a hardware component: the equipment installed in the field for signal acquisition, monitoring and communication of the variables; and other software: the information capture program and the end user interface.

The process instrumentation plan is shown in Figure 3, according to ISA-S5.1.

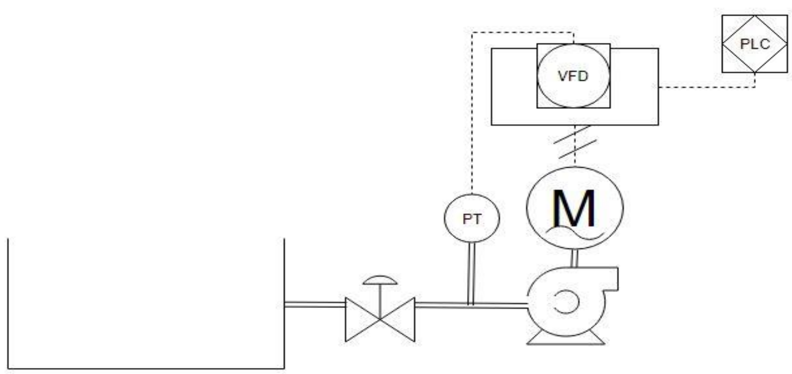

Figure 3. P&ID layout of system instruments. Source: own.

2.3. Plan Components

Crop irrigation is the system to be controlled within the proposed remote plant, which is shown schematically interconnected in Figure 3. This is made up of three components: 1) the part of hardware and equipment, which include actuators such as the frequency inverter, PLC controller for operating equipment, reading variable data, establishing communication, keeping records, etc. And computer work stations both locally and remotely; 2) the software used for both connectivity and to indicate process variables; and 3) the IoT platform as a technological web support.

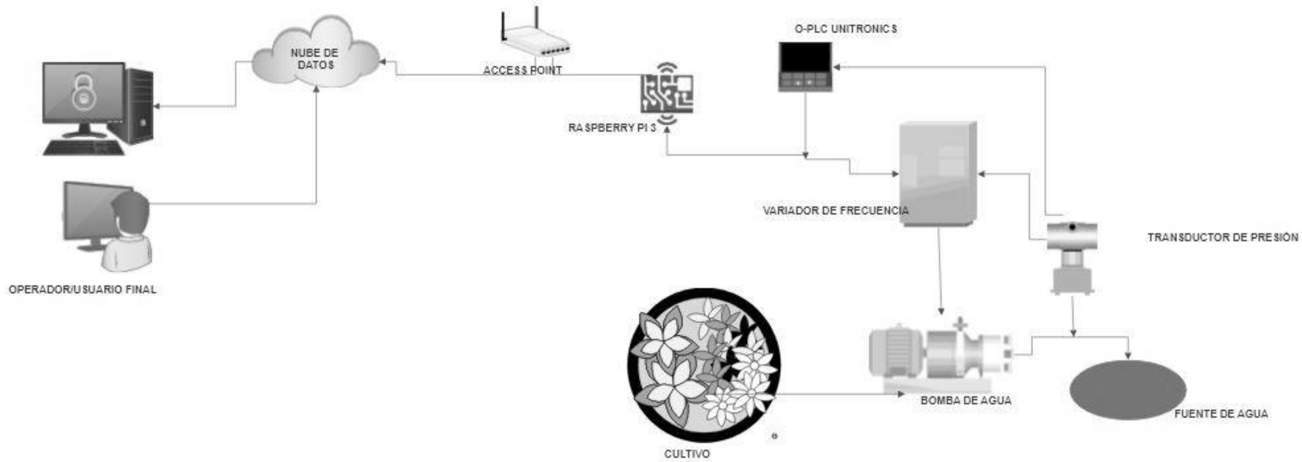

Figure 3. Basic structure of physical plant. Source: own.

The sizing of equipment is not within the scope of the article, since it is approached only from the control perspective. The pump is driven by a frequency inverter (VFD) provided to drive the centrifugal pump motor, which also is fed with a three-phase power supply, this VFD has a MODBUS RTU integrated communication protocol, although it is not limited to this fieldbus since another can be applied depending on the topology. A device with a MODBUS-RTU RS485 communication bus was chosen, which is one of the most used in the industry due to its simplicity of implementation and robustness of the physical layer.

The water pump is centrifugal type, in which the irrigation water reaches its working pressure according to the speed at which the motor rotates its impeller, figure 4, and for this it uses the frequency inverter.

Figure 4. Centrifugal water pump used in irrigation. Source: [12]

In this application the VFD integrates a way to control the pressure by means of a PI control loop (Proportional-Integral control) using a pressure transducer as feedback [13], Figure 5, with supply voltage coming from the drive itself (work voltage oscillates between 10-30 VDC) with signal output at 4-20 mA proportional to the transducer maximum pressure. The PLC is an OPLC type (Operator Panel + PLC), which optimizes the monitoring task by not requiring a computer on site, and establishes communication with the VFD (Modbus RS485) and with the monitoring system through ETHERNET.

. **Figure 5.** Pressure feedback transducer. Source: [14]

It is possible to integrate transducers that can provide additional data on critical variables for the process: soil moisture, temperatures, etc. and this is the key point of the supervision of variables, since determining which are those critical for the process, is what allows to optimize and keep track of the statistics and data that allow to make right decisions. Now, for the development of the interface part, the particular needs for the application were taken into account:

- Display current values of working pressure, pressure set-point, water pump status: motor current, and work pump status: if the motor it's run or stop mode, or if there is a fault during its operation.

- The graphical interface HMI must be light, so that when implementing the dashboard or instrument panel, the amount of data transferred does not collapse the communication between server and client.
- Give the remote crop system (plant, water pumps, among others) start and stop commands, set-point adjustment of water pump pressure that allows to maintain a constant and optimal water flow according to requirements of the plantation.

The final result of the interface is presented in Figure 6: on the left the use screen in the OPLC and on the right the dashboard or control panel seen from the end user side.

Figure 6. HMI interface: Local in crop. Remote in end user site. Source: own.

2.4. Application Developement

After establishing the guidelines required for the application, the system components were programmed according to the interconnectivity scheme planned in Figure 7 and where the main system blocks are located:

- The sensor at field, consisting of pressure sensors, (optionally humidity and temperature in the ground) and its wiring to the main PLC.
- The information acquisition node, consisting of the PLC and the local and remote monitoring interfaces.
- The web connectivity support, which is composed of the IoT connection platform implemented in Raspberry Pi, the internet connection (either by cable or Wireless type)

together with the dashboard and the integration between them through the Node-RED tool.

2.4.1. Web Connectivity programming

The development of connectivity was based on a combination of several platforms, which interact with each other to join the physical plant and the end user point.

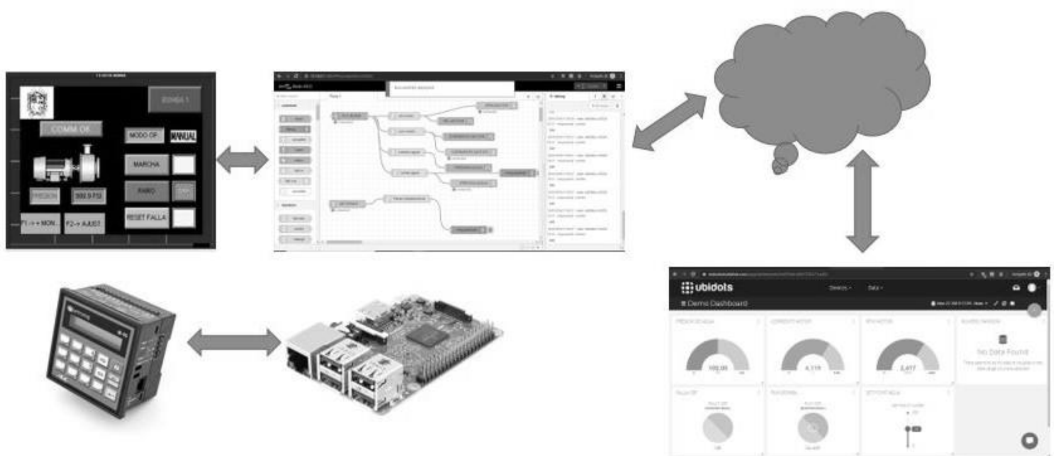

Figure 7. Information flow from PLC to dashboard. Source: own.

- The PLC has MODBUS-TCP functionality through an Ethernet port installed as an option, which allows the implementation of a slave node with the same PLC, which allows information to be directly and simplified to the integration platform. Connection to a third-party OPC server-client is also possible. The Node-RED system through the *node-red-contrib-modbustcp (node)* flow is established as a client to the network slave PLC.

- The Node-RED platform shown in Figure 8 connects the variables read by MODBUS TCP using the FC3 (READ HOLDING REGISTER) function, from the remote crop to the web dashboard, the visible graphic interface where the variables are presented graphically and numerical, linking the values transferred from the work node in the remote crop. This form is presented in development since in industry there are many platforms that allow, depending on the level of criticality, bandwidth communication, level field implementation and data security, being applied in a greater or lesser way, like the *Iot Particle Boron* embedded system, [15] which includes connectivity and even its own dashboard web platform.

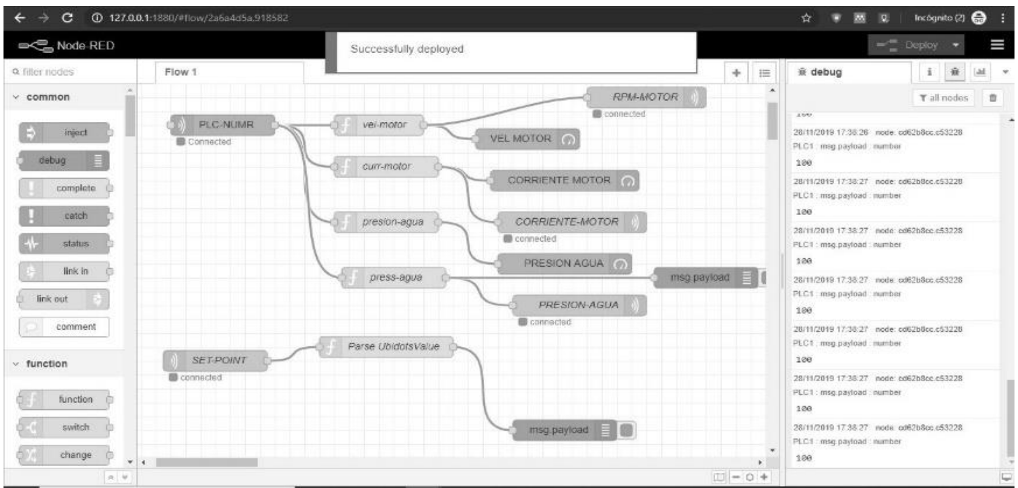

Figure 8. Node-RED flows system for TCP protocol. Source: own.

- The data goes from the application in Node-RED hosted at the Raspberry PI to the dashboard programmed in Ubidots, which is a cloud-web platform, which allows the information to be linked and displayed in a friendly way to the end user, who It has the information at hand and can make decisions about the state of the critical variable(s) that could affect the process.

2.4.2. OPLC software

The OPLC is programmed with its own software, Unitronics Visilogic which is downloaded from the manufacturer's website and is free to use. The language in which it is programmed is Ladder and it is comprised in the IEC61131-3 standard. The main function of the PLC is to serve as a connection node between the plant, taking the data from the sensors (humidity, temperature, water flow, etc.) and from the installed actuators (VFD connected by means of a fieldbus) and putting them available to the communication network through ETHERNET to be taken to the dashboard and presented to the end user.

2.4.3. Web presentación platform

The platform in which the data is taken for visualization and management to the end user is generated by means of the remote interface generated on the Ubidots dashboard platform, which shows gauges of variables from the remote crop by means of MQTT chains (MQ Telemetry Transport), which starts from the yield with the PLC concentrating the signals and data taken from the elements (actuators- VFDs, sensors, etc.) and routes them to the cloud. While Ubidots was used as a dashboard for its simplicity and ease of connectivity, any other platform can be used for this purpose; Even with the same Node-RED tool, this is also possible through *node-red-dashboard* functionality to generate a User Interface (UI).

The access level is a fundamental part of security, so the platform also restricts entry through authentication with username and password, to avoid possible interference in the process management.

3. Results

The results obtained during the implementation of the project are presented; since there is no standard methodology to quantify the performance of the system, the variables mentioned in the previous section were taken, as were the requests of the end user. Such indicators are shown in table No. 1 for hardware and No. 2 for software respectively.

COMPONENT	INDICATOR	REMARKS

Sensor and field actuators	Critical physical variables in crop development: constant irrigation flow, irrigation water pressure, ambient temperature, crop moisture, etc. They are consistent with the relevance of maintaining the optimum conditions of survival of the yield, that the plants do not deteriorate due to excess or defect of the required conditions of survival. Field sensors are implemented that have standard analog outputs (4-20 mA) and that the actuators (VDF) allow their integration.	The *de facto* standard for connecting analog signals is a current closed-loop (4-20 mA), but there may also be other variants, such as 0-10 VDC, 0-20 mA, etc. It is essential that actuators and controllers have the ability to accept these signals with these other forms.
Control and data acquisition element	All installed sensors and actuators communicate with the PLC that has field buses for communication with both the VFD actuator (via MODBUS RS-485 protocol, which receives set-point value for the integrated PI control loop as required for irrigation) and for the transmission of information through web connectivity by the ETHERNET interface. The modularity and scalability of this control hardware allows flexibility by having analog and digital I / O and the aforementioned communication protocols.	The PLC as central node hardware, must withstand intense humidity, heat and vibration conditions because it is in an unclosed environment. An enclosure (cabinet) suitable for outdoor use is the minimum required to house the PLC.
Communication of elements in field	In remote crop the pressure, humidity, temperature sensors are connected to the PLC node by means of 4-20 mA current loops (*de facto* standard) and additional, the VFD integrates its own (proportional-integral) PI controller for closed-loop control that simplifies the maintenance of irrigation pressure. The instruments do not depend on their own fieldbus, which allows maintaining reliability and flexibility for continuous change or improvement. MODBUS 485 communication is established with a speed of 19200 bps, which means that there are low delays in communicating commands to the actuator.	The sampling of analog signals for this PLC is rated at 100 ms per channel, at a resolution approx. 12-bit, which allows almost immediate readings and responses, although the sampling time increases as more analog channels are used for information gathering. Communication speed can be set in both VFD and PLC if wiring interference distorts data transmission.

Table 1. Hardware functionality indicators. Source: own.

COMPONENT	INDICATOR	REMARKS

Network performance - Internet	The communication rate of the information that leaves the remote crop to the IoT data integration cloud is very variable. Although the Raspberry PI 3B has an Ethernet port for speeds of up to 100 Mbps, the bottleneck would be presented in Internet access (data cloud). Because they are crops in remote locations, modems with mobile network (4G) connectivity are used that allow transmission speeds of 16.6 Mbps on average. The amount of data is low (signal frames of 28 MB / s) which allows a satisfactory speed and response for the requirement of response and display times.	The low latency is given by the amount of information to be transmitted; The greater the complexity of data, the greater the amount of bandwidth that should be available.
Ease of interaction with Web platform	The monitoring and visualization interface was designed to be as simple and practical as possible: allowing to verify the values of the important variables of pressure, temperature, VFD actuator status (current, motor voltage, working pressure, equipment failures if presented, etc.) command the speed and working pressure from the end-user side control station to the PLC at the remote crop. On the yield side, the PLC has its own HMI that allows field visualization of the VFD states and irrigation process values, although priority is given to the use of the remote interface.	The use of the Ubidots dashboard simplifies the task of presenting and taking the information and commands for both sides of the process, but more options can be contemplated that fit the requirements of each situation.
Control Settings	The control of the irrigation pressure is implemented locally by means of a PI closed-loop controller (proportional-integral) that allows programming the control variables of this loop: Kp (constant without unit of measure) and Ti (in seconds) (In VFD equipment that has a closed loop controller, the integral time Ti and not the constant Ki are programmed as applied in control theory). Typical values used in these applications: Kp = 5.0 and Ti = 1 s. Although the tuning of this control loop is done only once for the process and rarely needs to be adjusted, the control is more focused on visualizing VFD operating variables and those that infer in the development of crop plants (pressure of water, temperature, humidity, etc.)	The user can remotely give commands to start and stop the water pump, adjust set-point values, pressure and speed limit, and display the response of analogic variables.

Table 2. Software functionality indicators. Source: self-made.

4. Conclusions

The implementation of the proposed solution for monitoring critical variables in a remote crop was carried out satisfactorily, being able to visualize the immediate values of the irrigation in it, with acceptable response times. By improving the internet connection speed, shorter response periods can be achieved that allow more appropriate end-user intervention.

The latency in the process response of the frequency inverter is a factor that delays the arrival of the information to the end user, since this actuator when executing the water pressure control loop together with its other processes is a factor to have in account for the implementation of future developments; either with drives with better process times, or taking control loops to the installed PLC.

The process of articulating the information between the remote plant and the end user was complex, since the way to take the process variables from it to the data cloud depends largely on whether an implementation will be done from scratch, or with control equipment already operational: if PLC programming can be accessed, it is convenient to use direct communication with embedded protocol in client-server mode. If programming cannot be modified, using OPC (Open platform connectivity) type architectures is the most practical.

With the tools presented in this article, it is possible to approach the development of a SCADA system implemented discreetly with the elements that compose it, in such a way that, for low complexity applications, or where advanced functions such as crossing of variables are not required, trend logs, alarm and fault traceability modes, among others, can offer more tailored solutions for applications.

Although the exposed project complies with what is requested by the client, it is left as the basis to improve, expand or adapt to other possible applications, where it is required to monitor and control more complex processes, with integration and communication challenges in the cloud, perhaps even with compliance with increasingly rigorous standards.

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