Supervisory Control and Data Acquisition Software for Drip Irrigation Control in Olive Orchards. An Experience in an Arid Region of Argentina

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ABSTRACT

The proper management of irrigation systems is a key factor to achieve an efficient use of water and an adequate crop production. The use of new automatic control and communication technologies, offers a set of tools for data gathering and analysis, and assists agronomists and farmers to take better decisions in order to develop a sustainable agriculture, able to maintain its productivity and to be useful to the society in the long term. This work presents the implementation and set-up of a Supervisory Control and Data Acquisition (SCADA) system designed to supervise and control a drip irrigation system. The irrigation system is installed in a young olive orchard, located in San Juan, an arid region fully dependent on irrigation. The main task of the system is to gather and display the information coming from the field devices (soil moisture sensors, weather station, water flow-meters and programmable-logic-controller (PLC) for commanding the irrigation system) and automatically control the irrigation. The main screen of the SCADA software presents current information related to the process and, in other tabs, gives a detailed report of data. The gathered information is saved to a data base that can be accessed by different users, allowing the participation of other users, such as irrigation advisers, laboratories, quality control, maintenance, etc. Information can be accedes locally, through internet or by other means. Results of this experience show that it is possible to apply new technological tools to manage the irrigation process as a way to improve its efficiency.

INTRODUCTION

In the province of San Juan, located in the center-west of Argentina, farmers are forced to use drip irrigation systems for theirs olives crops due to the low level of summer precipitations (120 mm per year), high ETo (1700 mm per year), high temperatures, low air humidity, and irrigation water scarcity.

Proper management and supervision of irrigation systems are significant factors for achieving an efficient use of water and an adequate fruit production.

Most of the drip irrigation systems installed in the area are manually controlled and, in general, the irrigation program is based on the grower experience or statistical analysis of crop evapotranspiration (ET_c) data. System supervision to determine the correct operation of the irrigation system is also a human task performed irregularly, so fails or problems in the system are belatedly identified and resolved.

In order to improve the performance of pressurized irrigation systems in terms of water consumption, to evaluate in real time its performance, and to determine the irrigation schedule remotely, it is needed the inclusion of new technologies that already are available in the market. Playán and Mateos (2006) mention that specific objectives of modernization include: increasing water productivity, increasing the cost effectiveness of funds, increasing the reliability and flexibility of irrigation deliveries, accepting the demand of other users, and meeting environmental requirements.

In the last years, control systems and process automation have played an important role in the industry and technology development. As shown in Auernhammer (2001) and Zhang et al. (2002), the agriculture is not beyond this trend. The implementation of new technologies in sensors, actuators, automatic control and data communication offers a set of tools for data gathering, analysis and control. These elements can be integrated in a Supervisory Control and Data Acquisition (SCADA) system, allowing farmers or agronomists a better and ease decision making in order to develop an efficient and sustainable agriculture.

A SCADA system comprises the information collecting from one or more distant nodes, transferring it back to the central site, carrying out any necessary analysis and control, and conveying back the required actions to the process control (Bailey and Wright, 2003). Nowadays, SCADA systems are vital components of most industrial structures, and are progressively being included in irrigation control systems (Duran-Ros et. al, 2008).

This work presents the implementation and start-up of a SCADA system designed to remotely supervise and control a drip irrigation system. The SCADA software combines in a data base, the measurement of different variables, indexes and parameters related to the soil water and weather. This tool allows presenting then the information in form of historical graphics, so the grower has better information to make decisions on efficient irrigation management.

MATERIALS AND METHODS

This paper presents the development and field implementation of a SCADA designed to remotely supervise and control a drip irrigation system.

The user interacts with Human Machine Interface (HMI) to control the drip irrigation system and monitor the measured variables. This HMI was designed using advances techniques with LabVIEW graphical software (Bitter et al., 2006), National Instruments. Tools and structures available from LabVIEW (NI Developer Zone 2012) were used to develop the program modules corresponding to automatic control, data-base, access control, priority levels, resources management, web cast, among others.

Experimental drip-irrigation system

The head of the drip-irrigation system included a water pump and a screen filter. Water was provided from a reservoir, located next to the control room. The main irrigation pipe-line was divided into four secondary pipe-lines, each with a solenoid valve. Finally, each secondary line fed eight drip laterals of 40 m length, with auto-compensated emitters of 2 l /h every 0.80 m (Fig. 1).

The experimental drip irrigation system was installed in an 'Arbequina' olive orchard located in San Juan (31°39'S, 68°35'W), an arid region in Argentina. The orchard has a tree space of 6 x 2 m.

The orchard was divided into four smaller management zones (MZ), named MZ1, MZ2, MZ3 and MZ4, corresponding to each secondary irrigation line. For each MZ two measurement points has been assigned, block 1 and block 2 (B1 and B2).

Each MZ was irrigated independently, by activating its corresponding solenoid valve. This allowed simultaneous evaluation of different irrigation treatments (e.g. reference treatment and water deficit treatment).

SCADA hardware description

Due to the layout and characteristic of the drip irrigation systems, a centralized structure has been considered for control and monitoring (Petruzella, 2010). Therefore, decisions are made by a computer that centralizes the information. Fig. 2 depicts the elements that are part of the SCADA: a Personal Computer (PC), where the monitoring and control software is installed, a Programmable Logic Controller (PLC), four remote nodes installed in the field, a weather station, and a communication system in a point-multipoint topology that provides the data link between the different devices and the PC.

A Siemens PLC, model S7-200, has been used (Tubbs, 2007). The PLC receives commands from the PC to control the water pump and the opening or closing of the four solenoid valves of the drip irrigation system. The PLC, in turns, transmits to the PC the state of the pump and the valves.

A pressure sensor and a flow and volume-meter were connected to the analogical ports of the PLC. These sensors allow monitoring the pumping equipment.

Four remote nodes, one for each MZ, were installed in field. Each node consists of a datalogger that registers every five minutes the information from the all sensors installed in the MZ (Fig. 2). Information collected in the data logger was transmitted to the central computer. Each SCADA node was powered by a solar energy system (10w solar panel, voltage regulator, and 12Amp/h battery).

An electromagnetic water flow-meter and volume-meter (MR-Technologies) was installed at the beginning of each irrigation sub-unit in order to measure the water flow. The sensor was connected to the data logger through a RS-485 bus.

Two measurement points were defined (block 1 and 2) in each MZ; each block has two volumetric water contents sensors (ECH2O EC-5 Decagon, with analog output signal) installed at 30 cm and 60 cm depth, and two TUBULAR capacitive water content sensor with digital output installed at the same depths (Schugurensky and Capraro, 2008). Both sensor type were calibrated in laboratory and on field in order to perform a direct and continuous measurement of the gravimetric soil water content (Cobos and Chambers, 2010), enabling to perform an on-line closed-loop control of the drip irrigation system

A Davis Vantage-Pro 2 weather station was used to measure climate variables and reference evapotranspiration (ET_0).

The data link between the PC and the different remote devices was implemented using XBee-PRO (Digi) radio frequency (RF) modules that operate at 2.4 Ghz (free band) (Rappaport, 2002). A point-multipoint topology was implemented. The XBee-PRO module, in the base station, was installed at 8 m high, with a 20 dBi omnidirectional antenna. This module was connected to the PC through a RS-485 bus. The XBee-PRO modules in the remote nodes, the PLC and the weather station were installed at 4 m high and equipped with a 9dBi omnidirectional antenna. The data link between each device and the RF module was resolved with a RS-485 bus.

RESULTS

SCADA software description

The software is an application specially intended for being installed in a PC, located in a remote control-room. The software main task is to gather and display the information from the field devices in real-time.

The instantaneous values of all these data are registered every five minutes to generate a data-base that can be accessed by different users, allowing the participation of other areas or specialists, locally or through internet.

The software allows the user to perform continuous monitoring of the weather variables. The software displays the ETo accumulated in the last hour, and during the day and month in progress; in these application the user can set a period of interest to know the accumulated ETo. In the same way, the total water applied in each MZ in the last irrigation, the day in course or along an irrigation strategy period, can be displayed. These two parameters, the accumulated ETo and water applied, allow appropriate follow-up of irrigation strategies carried in the orchard.

The program can be accessed by one user at a time (unicast), having access priority the system administrator, accessing from the main PC. Fig. 3 shows the main screen of the SCADA software. All the instantaneous information related to the process is presented in the screen. The user interface has also five tabs.

1. SCADA. The upper left area of this screen shows the information about the actual state of the drip irrigation system: water pump (on/off), electro-valves (on/off), pressure and water-flow in the main irrigation pipe. The upper right area presents the information provided by the weather station. Current values of air temperature (ºC), air humidity (%), and last day ET_0 (mm) are presented in form of vertical bars. On the bottom of the screen, current values of the irrigation performance are presented, corresponding to each management zone. This information is organized in four fields with the following content: a tag that indicates the irrigation strategy which is currently running, elapsed irrigation, instantaneous water flow, water applied and finally, the gravimetric soil moisture level at the different pre-established depths.

2. Soil moisture. This tab displays actual and historical soil moisture values of each measurement point. Accumulated applied water can be displayed graphically for each management zone.

3. Drip irrigation control. In this tab are placed the commands and parameters to control the drip irrigation system. The opening and closing of each solenoid valve can be performed independently or at the same time. Each valve has a controller that can be configured in the following modes:

Manual mode. The screen presents a button that open or close the solenoid valves of the secondary lines. The last 10 operations are showed in a table in this mode.

Timed mode. Secondary pipe-line valves can be activated cyclically. The user only has to define the time elapsed between irrigations and irrigation time.

Automatic mode. In this mode, valves actuation is based on the current soil moisture level, giving as result a hysteresis cycle between the operations boundaries (upper and lower bounds). When the soil moisture is lesser than the lower bound, the irrigation is activated until soil moisture exceeds the upper bound and irrigation is deactivated. The user can define the soil moisture boundaries and sensor depth used to measure the soil moisture level.

Historical data (water pump operation, electro-valves on/off operation, pressure and water-flow in the main water line) and fault detection alarms are also presented in this tab.

4. Weather station. This tab shows historical weather information data and ET values. Current and historical ET_c is calculated and displayed incorporating crop coefficients values (Kc) obtained from any of the available information. In the lower part of this screen, current information from the weather station is displayed, in form of vertical bars. In addition, a check box for each weather variable enables the historical display of the data in form of a XY plot. The user can select the variables to be plotted, change the type and color of the line, vary the ranges and perform zooming operations.

5. Configuration. Allows the user to setup parameters of the SCADA software, configure the communication network, define and assign the sensors, and access to the pump and valves controller (PLC) of the irrigation system.

The PC gives access to the SCADA software, where the user can monitor, in real time, all variables related to the process. It is also possible to program the irrigation schedule for each MZ, based on the defined irrigation strategy (Fig. 3).

SCADA operation

The hardware installed and the software developed have resulted in a robust system of monitoring and control. Main features of this system are simple operation, easy maintenance, low cost, and fact that provides a very useful technological service for fruit grower or for scientific use. As expressed in Zhang et al. (2002), the development of a system with these characteristics, as an approach to precision agriculture, generates a direct impact on the agricultural profitability and benefits of the environment.

The SCADA system was used to perform several experiences related to RDI strategies in olive orchards, applying different irrigation treatments in different MZ and in different phenological stages (Pacheco et al. 2011; Vita Serman et al. (2011).

Regarding to the management of the irrigation system, the SCADA system showed a high degree of robustness. When failures occurred in the system, warning messages were reported correctly. The start time and time of irrigation sequence were accurately handled.

When the irrigation controller is configured in timed mode, irrigation is performed using water balance methods (Villalobos et al., 2000), and the ETc data can be calculated within the software. In this case, the behavior of the Soil water content works as a useful tool for analyzing scheduling performance.

In automatic mode, irrigation actions are based on automatic measurements of soil moisture, ET_0 level and amount of water applied in previous irrigation cycles. In this mode, optimal irrigation sequences are applied to each MZ, according to the defined treatment, and based on the current requirements and future demands.

CONCLUSIONS

This experience shows that it is possible to apply new technological tools (in information and communication technology - ICT) to manage the irrigation process as a way to improve its efficiency. In regions with lack of water, this SCADA system could be able to increase water efficiency.

The system has operated successfully for long periods of time; relevant information has been obtained about the drip-irrigation system performance, water use, and weather variables. It is expected to extend this experience to larger and commercial olive groves with more complex irrigation systems.

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Figures

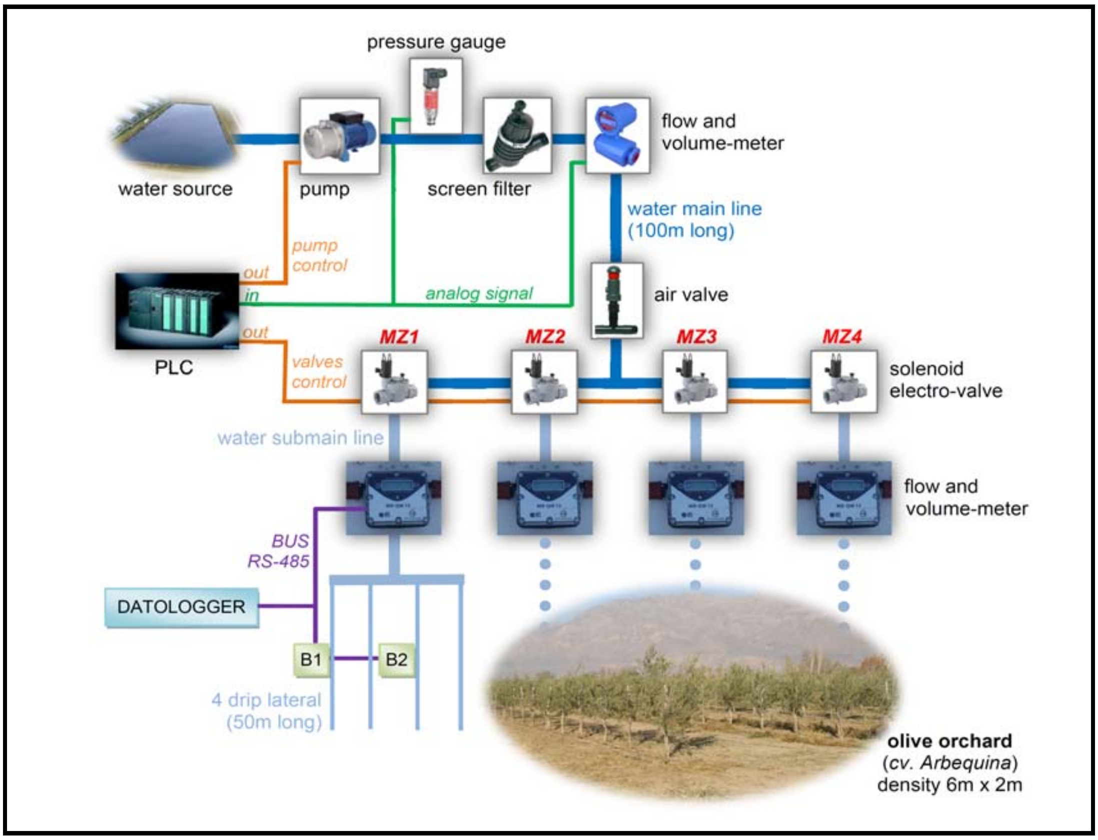


Fig. 1. Schematic of the experimental drip-irrigation system and distribution of control and monitoring equipment.

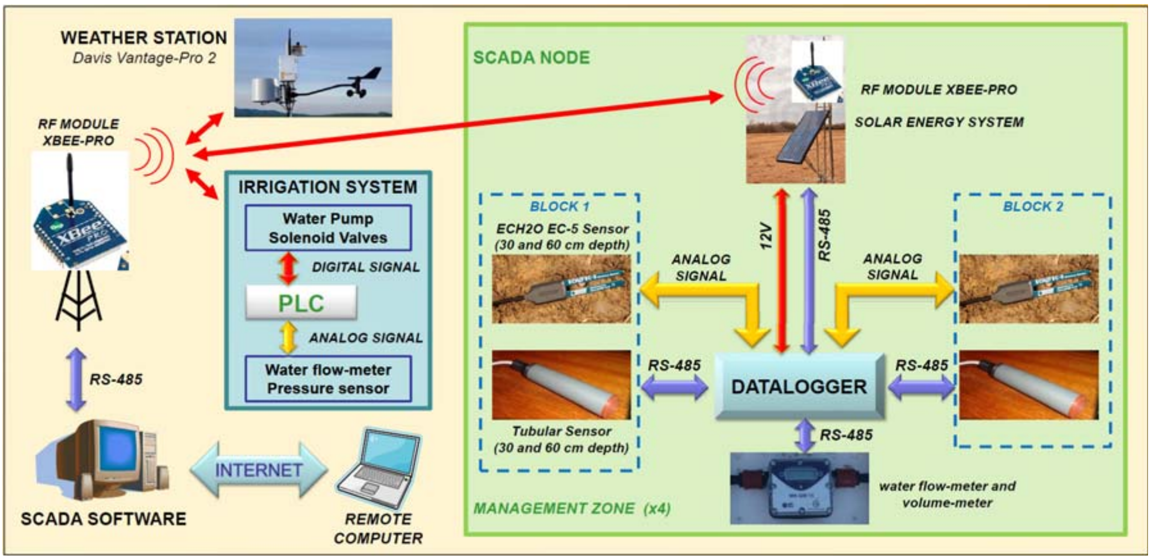
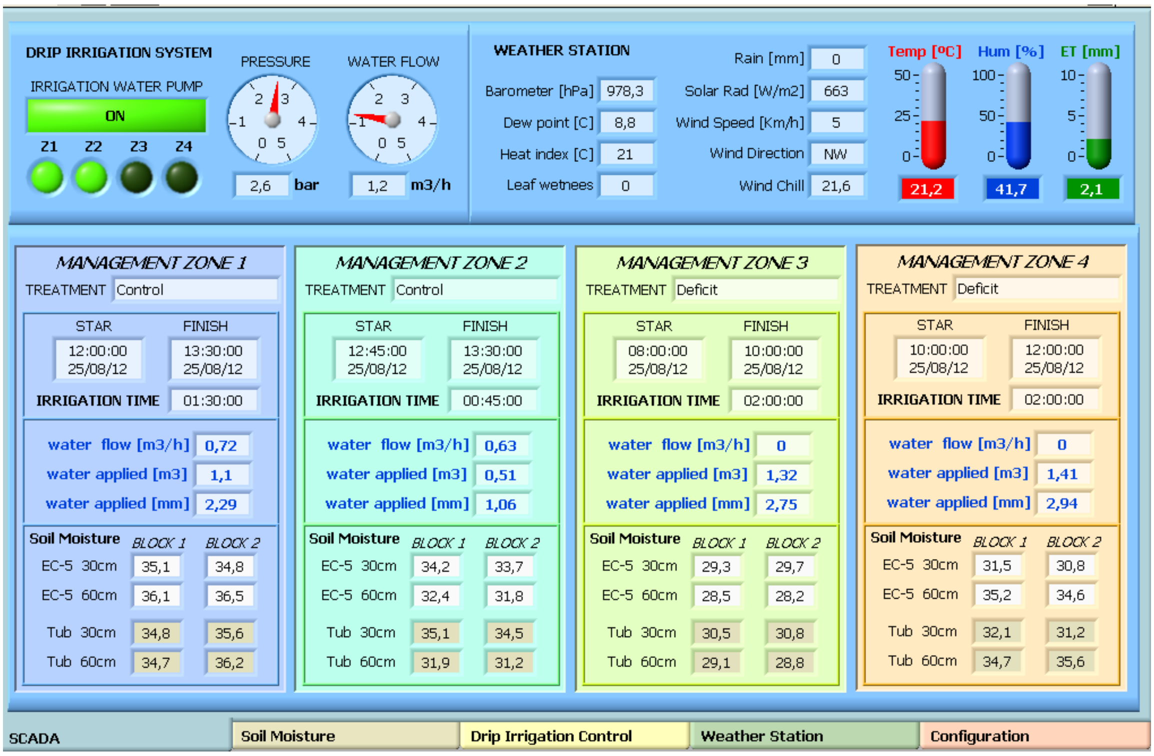


Fig. 2. Diagram of the SCADA system developed.



DRIP IRRIGATION SYSTEM

IRRIGATION WATER PUMP: ON

PRESSURE: 2,6 bar

WATER FLOW: 1,2 m3/h

WEATHER STATION

Barometer [hPa] 978,3
Dew point [C] 8,8
Heat index [C] 21
Leaf wetnees 0
Rain [mm] 0
Solar Rad [W/m2] 663
Wind Speed [Km/h] 5
Wind Direction NW
Wind Chill 21,6

Temp [ºC] 21,2
Hum [%] 41,7
ET [mm] 2,1

MANAGEMENT ZONE 1

TREATMENT Control

STAR 12:00:00 25/08/12
FINISH 13:30:00 25/08/12
IRRIGATION TIME 01:30:00

water flow [m3/h] 0,72
water applied [m3] 1,1
water applied [mm] 2,29

Soil Moisture	*BLOCK 1*	*BLOCK 2*
EC-5 30cm	35,1	34,8
EC-5 60cm	36,1	36,5
Tub 30cm	34,8	35,6
Tub 60cm	34,7	36,2

MANAGEMENT ZONE 2

TREATMENT Control

STAR 12:45:00 25/08/12
FINISH 13:30:00 25/08/12
IRRIGATION TIME 00:45:00

water flow [m3/h] 0,63
water applied [m3] 0,51
water applied [mm] 1,06

Soil Moisture	*BLOCK 1*	*BLOCK 2*
EC-5 30cm	34,2	33,7
EC-5 60cm	32,4	31,8
Tub 30cm	35,1	34,5
Tub 60cm	31,9	31,2

MANAGEMENT ZONE 3

TREATMENT Deficit

STAR 08:00:00 25/08/12
FINISH 10:00:00 25/08/12
IRRIGATION TIME 02:00:00

water flow [m3/h] 0
water applied [m3] 1,32
water applied [mm] 2,75

Soil Moisture	*BLOCK 1*	*BLOCK 2*
EC-5 30cm	29,3	29,7
EC-5 60cm	28,5	28,2
Tub 30cm	30,5	30,8
Tub 60cm	29,1	28,8

MANAGEMENT ZONE 4

TREATMENT Deficit

STAR 10:00:00 25/08/12
FINISH 12:00:00 25/08/12
IRRIGATION TIME 02:00:00

water flow [m3/h] 0
water applied [m3] 1,41
water applied [mm] 2,94

Soil Moisture	*BLOCK 1*	*BLOCK 2*
EC-5 30cm	31,5	30,8
EC-5 60cm	35,2	34,6
Tub 30cm	32,1	31,2
Tub 60cm	34,7	35,6

Fig 3. Main screen of the SCADA system. Real time supervision of a drip irrigation system, weather variables, last irrigation application (time and quantity) and soil moisture at different depths.