An Automated Irrigation System for Rice Cropping with Remote Supervision

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***Abstract*-Rice cropping farms are significant loads in power systems due to the large amount of electrical energy required by the irrigation system. In Brazil, power companies invest in research to improve energy efficiency of this type of load. This paper presents an automated irrigation system based on supervisory control (SCADA) and wireless communication. The main objective of the project is to monitor and control the level of water in the crop, which represents an important impact on energy efficiency and water consumption. Specific characteristics of rice cropping irrigation was taken into account, such as large distances involved and different working schemes of water pumps. A complete solution is presented and it includes equipment description for reliable communication and supervisory features.**

I. INTRODUCTION

Automation technologies are being increasingly applied to agriculture to reduce costs and increase production. In rice cultivation, the automation of the irrigation system plays an important role in controlling the use of electricity and water to ensure the quality of grains.

Unlike other crops, which can use irrigation systems based on water sprinklers or pivots, irrigation of rice is done by flooding or soil saturation. This affects, in general, two factors of great environmental, economic and supply relevance: electricity consumption and water consumption. In Brazil, for example, the impact is so important that utilities invest in energy efficiency programs and planning for energy supply in rural areas according to the harvest period.

Studies show that the appropriate level of water contributes to the quality of grains and affects the incidence of pests and diseases, weed populations and the availability of nutrients in the soil. Irrigation techniques, such as reducing the height of water level, maintenance of intermittent flooding or saturated soil are also studied and implemented to save water and electric energy. Such techniques require much more supervision and control than in a traditional system of continuous flooding.

A typical irrigation system includes a reservoir or water channels and a system for pumping water. An automated system should include water level sensors, an electronic controller for hydraulic pumps and a supervisory system for monitoring and establishment of set points [1-3].

The biggest challenge for this type of automation is the reliability of communication between the sensors deployed in the field and the supervisory system [4-7]. The communication between the sensors and the supervisory unit is done by means of a wireless link, due to the large dimensions that rice fields may have.

From the applicability point of view, automation should allow easy control of plant parameters, in order to reduce resistance of farmers to the use of new technologies. At this point, the supervisory system is crucial to interface between the farmer and automation devices.

This paper describes the implementation of a irrigation system for rice cropping based on SCADA (Supervisory Control and Data Acquisition) and wireless communication. The objective is to enable reliable and remote control of water level through a friendly interface for the operator. The final purpose of the project is to improve energy efficiency and rice production.

II. MATERIALS AND METHODS

A. Site Description

The experimental location is an area nearby Uruguaiana, in South Brazil. The state of Rio Grande do Sul is responsible for more than 50% of rice production in Brazil, and Uruguaiana is the largest rice producer in the country. The region has the highest thermal amplitude of the country, with monthly average temperatures between 8.7 °C in the winter and 31.7 °C in the summer. The climate is temperated and humid. The average monthly rainfall varies between 69,7 mm and 165,2 mm, and the annual average is 114,29 mm. The geomorphology of the landscape is predominantly grassland with undulating fields. Insolation varies between a minimum of 148 hours in June and a maximum of 283 hours in December, reaching an annual total of 2514 hours of sunshine. These climatic and geographical factors, together with the characteristics of soil composition and cultivated species, are taken into account by specialists to determine the parameters of supervision and management of farming, including the irrigation system [8].

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B. *Structure and Equipment Description*

The project comprises four levels of communication, as shown in Fig.1. The lowest level is the communication of field devices (sensors) with a controller, where wireless communication is used at this level. The second level is the wired communication between the controller and the actuators (electronic drives for pumps). The logic control of drives is implemented in the controller based on the information of the water level sensors. The control flowchart includes a safe operation mode activated if the communication between the controller and the highest levels is lost. The third level is the communication between the controller and the supervisory system. In normal situation, the supervision room is at the administrative head office of the farm, which can be miles away from the crop. In this case, the solution adopted is the use of telephone communication through GPRS messages. At the highest level there is the communication between the supervisory system and the user, through screens (windows applications) that allow monitoring and operating the system devices.

1. *Water Level Sensors*

Ultrasonic sensors were used to measure the level of water in field. The model (T30UFDNCQ) has a variable range from 300mm to 3m, 3.6 to 5.5 DC power supply, and serial output for connection to the wireless transmitter module. The transmitter modules (model DX80N2X2S2S) operate at 2.4GHz and contain two sensors each. The connection between the sensors and the transmitters is made by coaxial cable. For practical application, the sensors and the transmitter module are installed on rods, and share a compact battery. Fig. 2 shows the scheme for water level installation and range. A wireless gateway (model DX80G2M2S) receives the signals from sensors and transmits the measured data with the controller using MODBUS protocol.

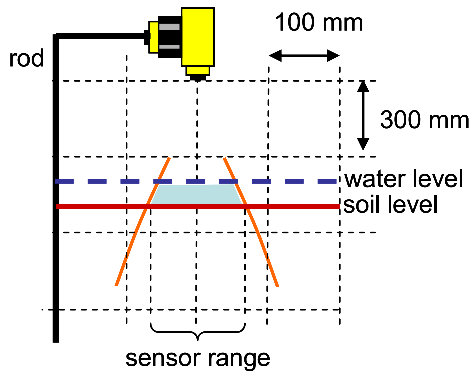

Fig. 2. Scheme of water level sensor installation

2. *Pumps and Drives*

The speed of the pumps is controlled by frequency inverters. The inverters used were the WEG CFW-10 model, which receive the command from the controller through 4-20mA channels. Due to supply constraints at the test site, the inverters also have the function of converting the single phase local grid to three phase.

3. *Controller*

The control logic of the project is implemented in the controller, which also has the function of integrating all elements of the system. The controller receives information from the sensors and sends the commands to the drives of the pumps. Supervision is established through the SCADA, which can monitor and change the controller parameters. If the communication with the supervisor fails, the controller starts to operate in stand-alone mode, with a subroutine based

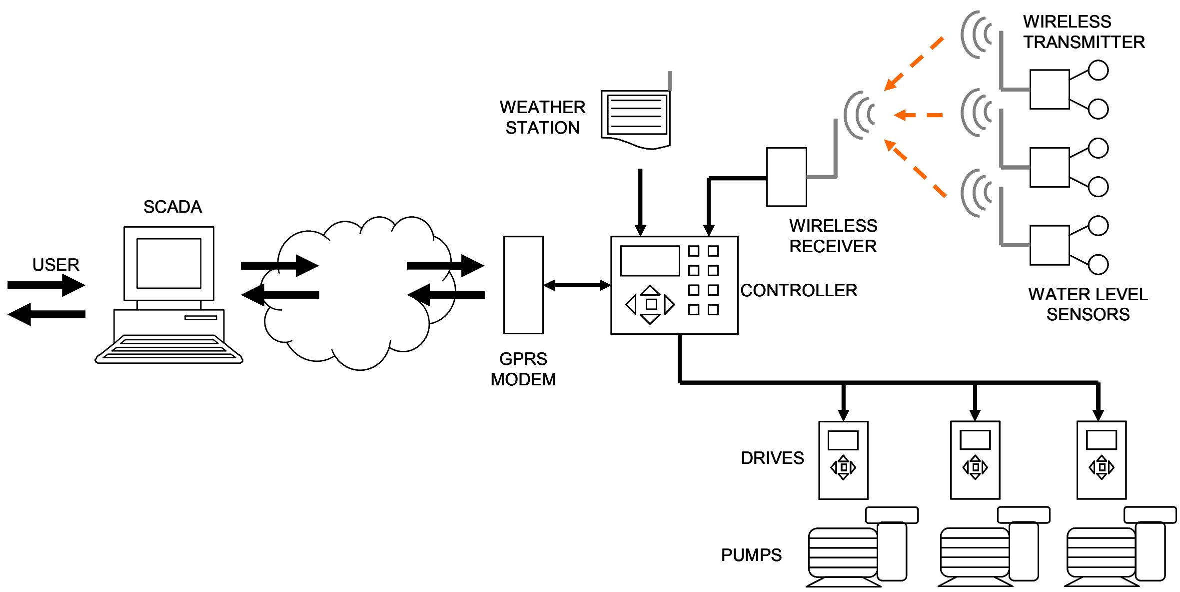

Fig. 1. Schematic diagram of the proposed automation system

on default parameters. Communication between the controller and the supervisory system is done by a GPRS Modem in DNP3 protocol. The choice of these standards is justified by the consolidated use of GPRS/DNP3 applications in power systems, such as operation of switches and remote controlled substations. The DNP3 protocol has time stamped variants of all data so that even with communication failure between the controller and SCADA, it is still possible to recover data to correctly reconstruct the sequence of events after the communication is restored. The BCM 2085B controller is used in the project. A particular feature of this controller, which is important to this specific application, is a large number of modules for serial communication ports.

4. GPRS Modem

The wireless telemetry unit, model G24 (Motorola / Itech) was used to establish communication between the controller and supervisory system. This model has the ability to automatically manage the GPRS connection and perform the compatibility of this technology to the DPN3 protocol transparently (without protocol conversion) with the supervisory system used.

5. Supervisory Control and Data Acquisition

The SCADA software allows monitoring and controlling, singly or in group, each communication level of the project and its elements. It also provides a friendly interface for the user and allows access to parameters and control variables of the crop.

Fig. 3 shows a schematic of the main supervision screen implemented in the supervisory E3, developed by Elipse Software company. Detailed description of the implemented features is presented in Section III.

6. Additional Equipment

Aiming to further improve energy efficiency studies and to establish relations between grain quality and climate conditions, a weather station and a power meter for each individual pump were included in the project. Except for the rain gauge, the variables of these devices are currently used only for monitoring, and they are not included in control logic.

C. Control Strategy

In large crops, the control of water level in conventional mode is done by employees who walk on the rice field with a shovel and open or close the micro-channels allowing the water to enter or to leave the sectioned area. In occurrence of heavy rain, for example, an employee opens the terminal of the irrigated area so that the surplus water leaves the section. It may take 2 to 4 days to fill a rice field with water.

The pumps in normal crops are low-speed and therefore coupled to motors by pulleys and belts. They operate about 21 hours a day, stopping during the utility peak period. In Brazil, there is a differentiated charging for the period of peak energy consumption (according to the load profile of each utility). Moreover, there is also diferent energy pricing for dry and wet periods. During weekends and public holidays the system operates 24 hours a day. Exception is made in occurrence of heavy rain, when the machines are shut down. The control strategy was constructed based on these operation conditions.

Fig. 4 illustrates the concept of logical drive (the time scales vary from minutes to days, depending on the weather conditions). The pumps have two schemes of operation (Fig. 4a). During the filling of the crop, they are continuously connected in compliance with the schedules of tariff differentiation. During the maintaining of the water level, the frequency of the drives is adjusted according to the difference between the reference value of water level and the value

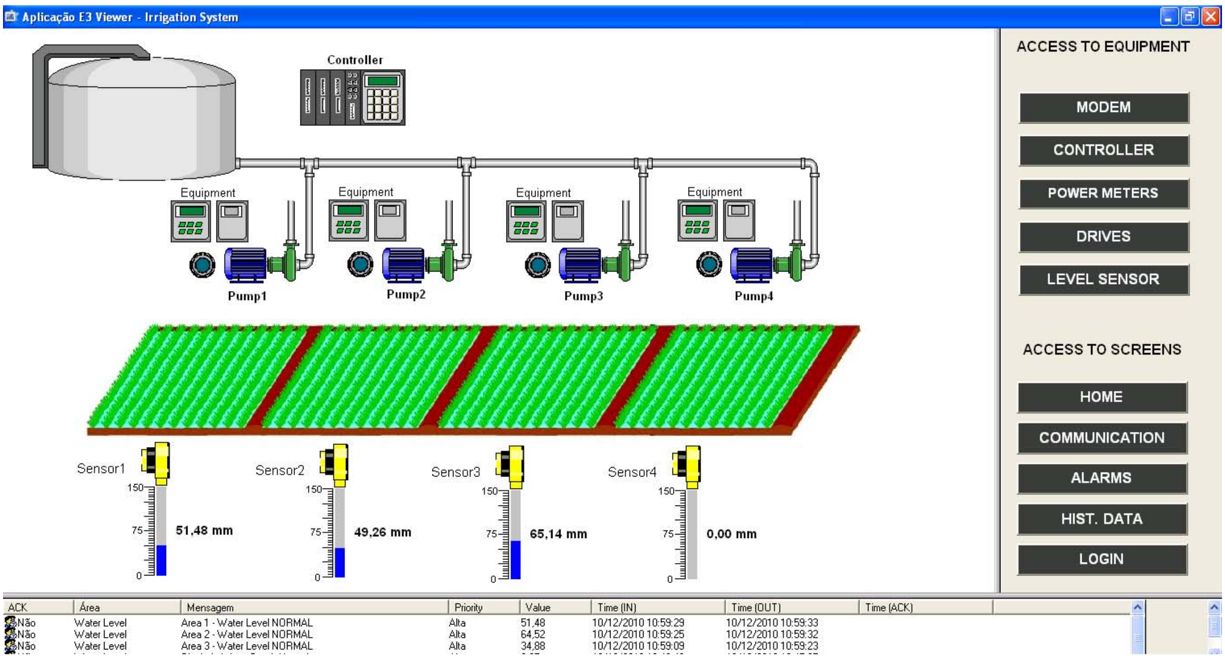

Fig. 3. Overall view of main supervisory screen

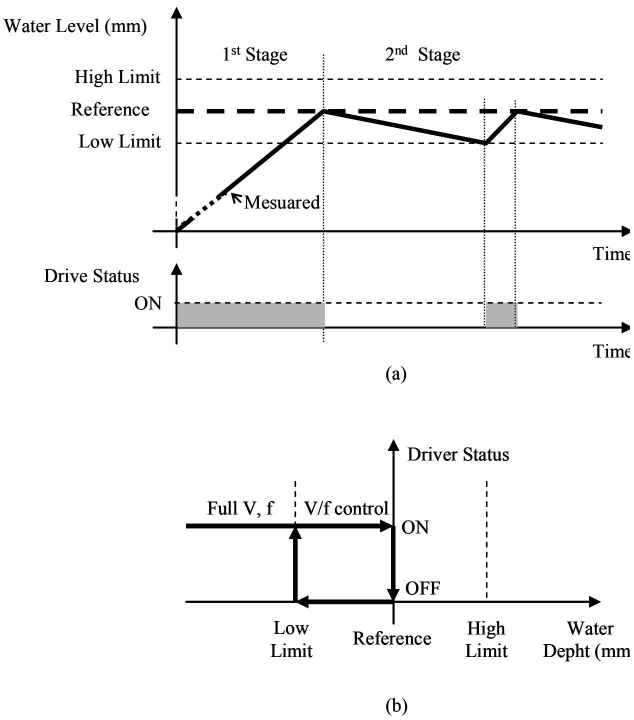

Fig. 4. Work scheme of electrical drives

measured by the sensors. A hysteresis loop (Fig. 4b) based on limits of water level is established to prevent the pumps from switching on and off in a short period of time. In the interval between the lower limit and the reference, the drive follows a V / f characteristic previously adjusted. Below the lower limit, the drives are fully activated, according to their rated values of V and f. The upper limit of water level is used to trigger an warning that requires manual intervention to open up sections of the field, because this action is not automatic in this project.

The flowchart of the controller is shown in Fig. 5. Two tests were established to switch the flow from normal operation to standard operation. In case of loss of communication with the supervisory system (communication test), an standard control algorithm is followed. And in case of heavy rain (climate test) the pumps are not activated. The time control (differentiated tariff period) is not shown in the flowchart of Fig 5.

III. IMPLEMENTATION AND RESULTS

The experimentation tests are being carried out in four irrigation areas of small scale (10m x 20m) for evaluating the performance of the proposed system. Three areas are automatically controlled so that the water level is within an acceptable range of values. In the fourth area, the conventional control system (i.e. without any automation) was adopted for the purpose of comparison. Table I summarizes the parameters adopted in the project.

From the main screen of SCADA application (Fig. 3) it is possible to access, by clicking on the equipment icon, the following features:

- Monitoring: status (on / off) and power consumption of each electric motor, water level in each area, weather variables, status of communication between the sensors and the controller, and between the controller and the supervisory.
- Parameterization: controller set points (reference values and limits of water level, adjust of the ramp V / f for drives, limits for weather conditions and time tests). Fig. 6 shows the setpoint application screen used to stablish water level parameters.

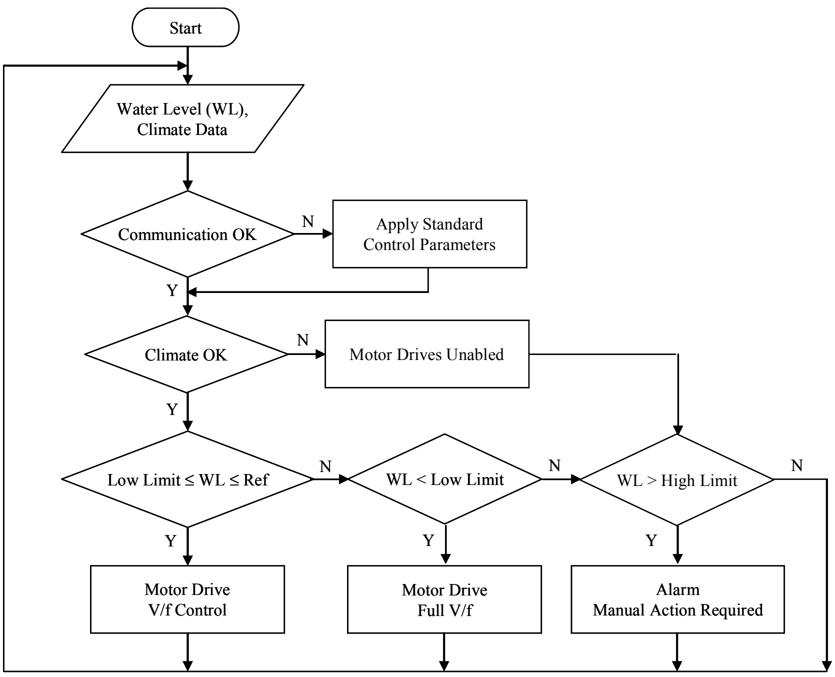

Fig. 5. Controller flowchart

TABLE I
PARAMETER CONFIGURATION

Area	Water Level Reference	Water Level Low Limit	Water Level High Limit
1	-	-	-
2	30 mm	20 mm	40 mm
3	10 mm	5 mm	20 mm
4	50 mm	10 mm-	70 mm-
Other General Parameters			
Time Constraint: 6:00 pm – 9:00 pm			
Rainfall Limit (per day): 25 mm			

The developed application has other screens to monitor the status of each individual equipment and weather conditions, to record data in database, to show historical graphics, and to register new users.

An important SCADA feature is the alarm management. It was developed an application which contains all information on all warning conditions (Fig. 7). For each source of alarm it is possible to set limits, the message on the event occurrence, its priority and the acknowledgment requisition.

The priority indicates how important the occurred alarm is. It may assume one of the following levels: *Low*, *Medium* or *High*. These levels can be used for filtering and sorting messages. For the irrigation system, the following situations are considered to be critical: malfunction of any equipment (characterized by communication failure or inconsistent reading), measured values above or below the critical parameters, activation of the irrigation system in adverse weather condition.

The application uses three types of alarms:

- Analog: used to monitor analog variables by specifying up to four warning levels, which are the LOLO (very low), LO (low), HI (high) and HIHI (very high). The monitoring of water level and energy consumption can produce this type of alarm.

- Digital: used to monitor a digital variable (or expression) by specifying alarms on the positive edge (1 or True) or negative edge (0 or False) of the event occurrence. The communication failure in any equipment or use of the pumping system in undue situation can produce this type of alarm.

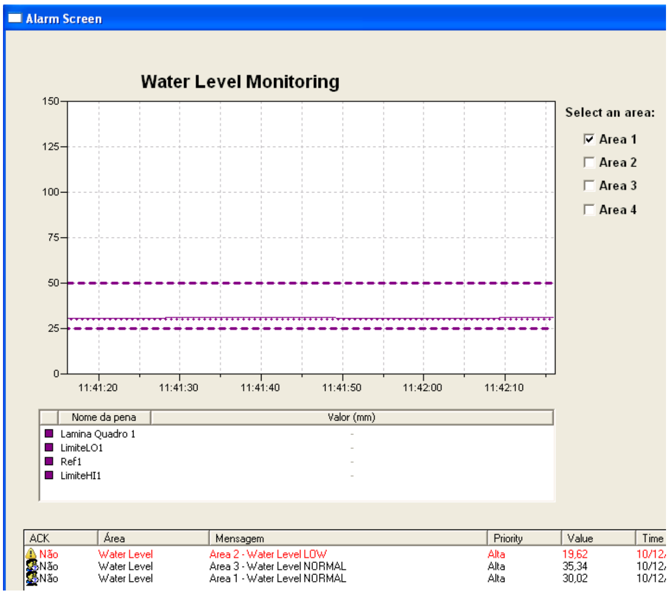

Fig. 7– Alarm Screen

- Rate-of-change: used to monitor short-term changes in a process variable. The rate is specified in variable unit per second. This type of alarm is used to identify data inconsistencies, such as the sudden increase or decrease of a variable that in normal situations has a low rate, for example, water level, temperature and power consumption.

A control column indicates that the warning must be acknowledged by the operator, so as to be removed from the alarm list, or if it is recognized automatically when the variable leaves an alarm condition. Whenever a source of alarm leaves the alarm condition, a message appears on the screen.

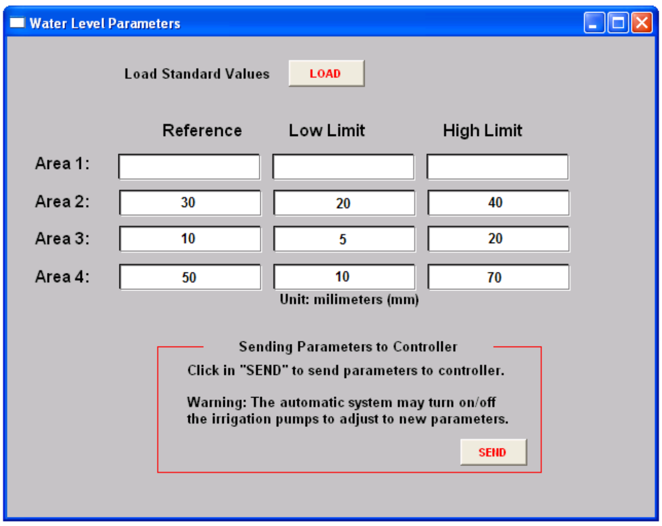

Fig. 6– Set Point Configuration Screen

IV. CONCLUSION

An automatic irrigation system for rice cultivation was presented in this paper. Its main features are: the use of a supervisory system for monitoring and controlling the irrigation pumping and the water level, and the use of a communication system based on GPRS to allow remote supervision. The control of the crop conditions is done by a dedicated controller, which eliminates the need for a computer on site. In addition, the controller has an interface that allows access to its parameters and also the implementation of a standard operation in case of loss of communication with the supervisory system. Critical situations such as malfunction of some equipment, adverse weather conditions and unacceptable levels of controlled variables can be quickly identified and addressed through the capabilities of the alarm screen of the developed system. The GPRS communication combined with the DNP3 protocol proved to be reliable for this application. The developed system will allow further research on the quality of rice, through the intersection of historical water level data and weather data during the test period. The system also contributes to the development of irrigation practices that allow optimal use of water and electricity.

ACKNOWLEDGMENT

The authors would like to thank the technical and financial support of AES Sul Distribuidora Gaúcha de Energia SA, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

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