Efficient IoT system for Precision Agriculture

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***Abstract*— The introduction of automation and telemetry systems in precision agriculture is an innovative approach that could conduct to the implementation of an information system that can provide data on irrigation during all year. Climate change and population growth contribute to a multitude of problems in agriculture and have an impact on farming practices. The need for an automation and telemetry system for irrigation is emphasized by the market's interest in having access to fully automated monitoring and automation solutions for energy-efficient and cost-effective agricultural crops. The advantages of system architecture presented in this paper consist in very low energy consumption, low management costs, scalability, forecasting functions, diagnosis, enlargement facility lead to an important technical impact and high potential for marketing. The aim of this paper is to use an integrated automation and telemetry solution in precision agriculture, taking into consideration the energy efficiency criteria and the latest technologies available on the market.**

Keywords*— *Precision Agriculture, irrigation, forecasting, telemetry system

I. Introduction

The IoT can be a plant disease sensor or a smart station to monitor the pollution of the air or any other natural or human-made object that can be assigned an IP address and can transfer data over a network [1]. IoT platforms play a crucial role in ensuring reliable and accurate data regardless of the applications. Together with the devices, technologies and data transmission protocols IoT platforms can expand the applicability areas including medical domain, automotive fields, agriculture, etc.

Water management and irrigation programming have become the main subjects in numerous studies in the last years taking into consideration their increased importance in precision agriculture. Irrigation quality is an indicator of performance, the influence which can be perceived both directly and indirectly. The need for crop irrigation differs depending on the climate of the area, so energy efficiency and the economic use of water resources are strongly interconnected with the type of plantation and soil [2]. Protecting natural water resources through rational and effective use of water is one of the main challenges faced by the specialists, therefore concrete and sustainable measures are needed. Irrigated agriculture accounts for 20% of the total cultivated land with different irrigation solutions currently available, such as drip irrigation, irrigation surface leakage and sprinkler irrigation.

This article proposes an efficient energy system architecture for irrigation management, achieving improvement compared to the already existing solutions. In order to establish an optimal configuration of the system, the monitored parameters that have a high influence on crop productivity are presented, explaining the benefits of monitoring them. Further the main control methods used in irrigation management are illustrated. Next an integrated automation and telemetry solution for water management in precision agriculture is detailed, by considering the criteria of energy and economic efficiency, as well as the leading driving technologies presented.

The novelty of the work is represented by monitoring solutions for energy efficiency of the agricultural crops. The rest of the paper is structured as follows: Section II presents related work for precision agriculture, Section III discusses about parameters monitored in irrigation, Section IV presents the experimental data and lastly, Section V concludes the paper.

II. Related Work

Climate changes contribute to the problems in agriculture. To address these issues, the agricultural sector needs to adapt to the new technologies, for monitoring and transmitting the data. Farmbot is a device that is used to solve problems in agriculture, but on a small scale [3]. It also has an application that can configure and control Farmbot from your browser, laptop, tablet, or phone. The application has real-time manual commands and a module that allows creating routines execution. The application receives the user input commands so that it can create the type of farm. The MQTT Gateway is the interface between the web application and the Farmbot device. Decision Support System analyses the data collected by sensors and based on them they use algorithms that will optimize the events programmed by the system. For example, considering meteorological forecasting, soil moisture and crop type, Farmbot can decide what water needs to be used to irrigate the plants. All information collected is stored in a database [4]. FarmBeats is an IoT platform for agricultural practices that collects data from various sensors and drones with cameras. The FarmBeats system works even when weather conditions are not favourable. Data collected by FarmBeats system sensors is stored in a Cloud that allows them to store and analyse

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indefinitely. The architecture of the FarmBeats system consists of sensors and drones, sensors measure soil, specific parameters (humidity and pH) and transmit collected data to the IoT station using a Wi-Fi protocol. Unlike other solutions used in agriculture, the system is equipped with video cameras and drones that capture images and send them to the station via a Wi-Fi connection. The IoT Base Station - is powered by solar panels.

The British pioneer technology Kevin Ashton proposed in 1999 the term Internet of Things (IoT) defining interconnected devices that can communicate with each other [5]. This telemetry cloud testing platform uses different types of RTUs and sensors that monitor and transmit relevant information from selected locations, such as temperature, precipitation, light, or wind speed. The cloud testing environment provides to the platform a processing data from several different sensors that allow the analysis of environmental data through a large sample of RTUs [6].

RTUs transmit data to GSM / GPRS sensors to the cloud platform, where the data is processed in real time, is displayed in the web viewer application, with detailed information on power generation and optimized energy revenues. The system can be connected to other systems management for better use of resources, considering certain factors such as energy price, consumption trends and improved risk management [7]. The server architecture of the M2M telemetry software uses ADCON solutions for data visualization and interpreting. The operations performed at server' level include data downloads from Telemetry Gateway and data storage, extensions starts/stopping, providing data to customers, etc. [8].

III. PARAMETERS MONITORED IN IRRIGATION

Measurement accuracy is essential in agriculture. Parameters monitored in a plantation are dependent on the type of soil and the climate of the region.

A. Temperature and humidity of the air

Crops can be regarded as functions mainly dependent on temperature when irrigation is carried out suitable [9]. Temperature has a significant influence on seed germination, because in biochemical processes germination phases include hydration and enzyme activation; the plant development process is dependent on temperature.

High or low temperatures strongly influence the agricultural season and given that in the coming years this parameter will show a significant rise, so the amount of water required for irrigation will increase according to the requirements of evaporation. A numerical method has been demonstrated that at +2°C difference in temperature, it will increase the water demand of cultures with 19 % [10].

Each plantation requires a specific temperature; otherwise, the seeds will stay in the ground and will be exposed to the attack of some pests, diseases, or loss of germination. Another important aspect is that the optimal temperature does not generally correspond to vegetative growth, which differs from one vegetation to another.

Absolute humidity is the partial pressure of water vapor in wet air, usually expressed in millimeters mercury column. The partial pressure of water vapor in wet air and quantity of vapors contained in one m^3 of wet air, expressed in grams, are numerically equal. Relative humidity provides information with on the water vapor in the air, this parameter being in a strong interdependence with temperature. On the other hand, dew point temperature explains the relationship between relative humidity and temperature because, with an increase in relative humidity, a decrease in temperature occurs, and if the temperature falls below a certain limit, the air reaches the point where it will contain the most considerable amount of water vapor.

B. Temperature and humidity of soil

The soil is an essential resource in irrigation management, as it is a carbon storage tank. Soil humidity is identified as a critical parameter in precision farming. There has been demonstrated that monitoring of soil temperature and humidity are critical processes for precision agriculture. In some regions, irrigated farmers when soil moisture exceeds certain limit (50%) [11].

The frequency of irrigation depends on the equipment used for drip irrigation or the characteristics of deep wells. The primary objective of irrigation is to optimize plant water requirements, and this can be achieved through active monitoring of soil moisture. It is considered that soil moisture should be measured by sensors that do not have moving parts and do not require calibration [12]. Soil temperature is greatly influenced by solar and humidity radiation. Usually, the soil temperature is higher than the air temperature, and the propagation of the heat in the soil is a slow process [13].

C. Evapotranspiration (ET)

ET can be defined as a combination between water evaporation from the soil and/or surface and water transpiration through the plant tissues [14]. Based on ET other crucial parameters for agriculture need careful planning in order to ensure efficient management of water resources.

The total ET has components determined by weather conditions, potential transpiration and evaporation, the water of the soil, water stress effects on leaf area growth, etc. [15].

Important part of hydrologic cycle, ET influences the water balance from the moment it reaches the ground through precipitation until the residual water reaches the ocean.

The parameters that influence evapotranspiration are soil texture and residue cover, climate factors such as air temperature and humidity, crop related factors (growth stage, crop type), etc. Therefore evaporation (soil water loss) and transpiration (crop water loss) are two unwanted effects that appear simultaneously ensuring the unpredictability of evapotranspiration process [16].

IV. ARCHITECTURE OF THE IRRIGATION SYSTEM FOR PRECISION AGRICULTURE

The proposed telemetry and automation system consist in close monitoring of key parameters for culture. It also brings to attention an automation system developed for irrigation control and reducing energy consumption [17].

The telemetry process for the proposed system (Fig. 1) is performed with an ADCON telemetry station that will measure field parameters (soil and air humidity, soil and air temperature, etc.). These parameters will be transmitted to the SCADA

(Supervisory Control and Data Acquisition) system via a RTU (Remote Terminal Unit) and a communications server. To connect these elements to your PC, OPC (Object Linking and Embedding for Process Control) connections are required via a Gateway.

Automatic control and regulation are achieved through PLCs (Programmable Logic Controller) that implement the driving algorithms and command the drive elements. The communication is done using GSM modules to reduce the physical complexity of the network (wiring). The fuzzy control algorithms will be computed in Matlab and sent to implementation to a PLC that allows fuzzy control.

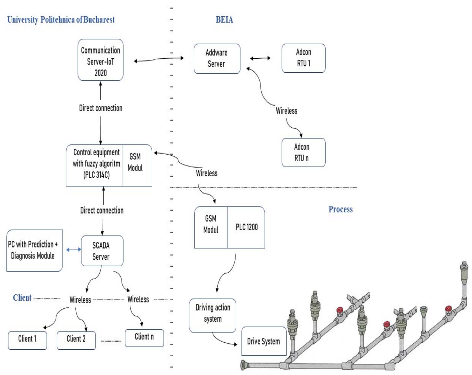

Fig. 1. Architecture of irrigation system

The functions of the SCADA system (adjustment, prediction, diagnosis) will be performed on a PC that has two-way connection means with the SCADA server and the PLC. It will have more customers depending on the number of users/beneficiaries of the telemetry and automation system.

Drive equipment (pumps, valves) have low power consumption to ensure increased system efficiency.

V. Experimental Data

In the experimental part rainfall, temperature, wind speed and humidity were measured from 15 to 15 minutes at the ADCON telemetry station over a period of 39 hours.

A mathematical model was developed in MATLAB in which we had input values of measured precipitation, perturbations, and output data – humidity of soil. In order to have a proper view of the telemetry and automation system, a comparison was made between the measured values from the ADCON station and the values calculated by using the MATLAB mathematical model.

The mathematical model MATLAB starts from the premise that the prognosis process of precipitation, represent a linear one and starts from a stationary mode that receives a step signal of a Laplace transform function.

Fig. 2 and Fig. 3 illustrate the distribution of measured data and mathematical–achieved data for precipitation and humidity.

In Fig. 2, "*real command*" represents the instantaneous value of precipitation in the selected area. At the same time, "*approximate real command*" is the amount of precipitation in the selected area obtained using a 3-day weather forecast. The graphs obtained show the differences between the forecasting platform used in our system and the real value of the precipitation. Thus, the form of the 2 graphs can be explained, where the values obtained by "approximate real command" (data obtained through the 3-day forecast) can be considered as an average of those obtained by "real command" (instantaneous data). For example, between minute 700 and minute 1000, the estimated precipitations were 0.2l / m², but, several dynamic values have been recorded.

In Fig. 3, the "simulated data" is the output value of the Matlab mathematical model, where the input is represented by the "approximate real command". The "real data" is the actual measured value of humidity after the precipitation.

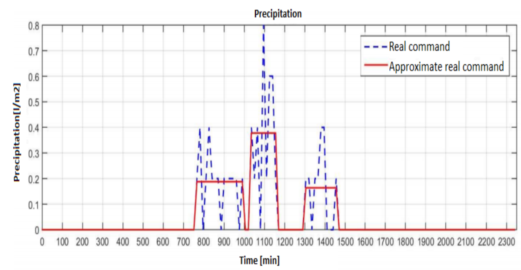

Fig. 2 Variation of precipitation

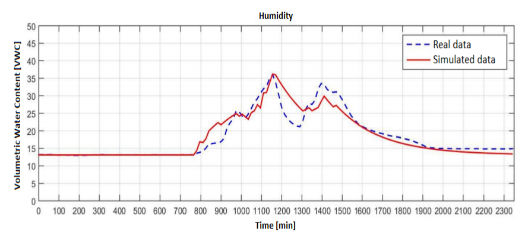

Fig. 3 Variation of humidity

It can be highlighted that the "simulated data" follows the form of the "real data" with an acceptable error. As can be seen in Fig. 2 and 3, the evolution obtained based on the mathematical model is roughly the same as that obtained in the real simulation. In conclusion, the calculated model is valid.

In Fig.4, the time-evolution of modelling error is illustrated and, using statistical analysis, the following modelling errors have been obtained:

- Average error: 6.49%;

- Maximum error: 34.34%;

The modelling error is mainly influenced by the variation in weather forecast and real rainfall. If the modelling error remains at a high value for a long period of time, this would allow the irrigation system to irrigate crops more often than necessary, which negatively influences energy efficiency (increasing the consumption of electricity and water). In the model presented, this modelling error has high values only for short periods of time, so it does not influence the irrigation system.

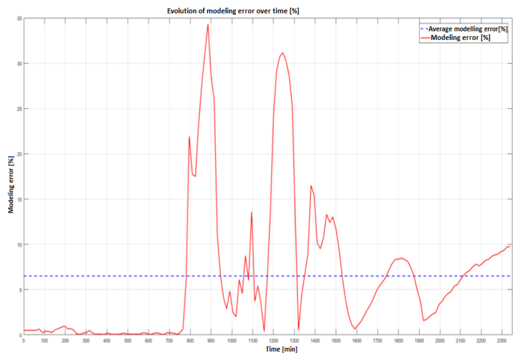

Fig. 4. Evolution of modeling error

Considering, the meteorological forecast of rainfall throughout two days, soil moisture is estimated at the site. For automation of the irrigation system, a fuzzy open-circuit command with input sizes (humidity and air temperature, solar radiation, wind speed, and soil humidity) is used, and the irrigation period is calculated at the output.

For example, crop irrigation is not recommended when humidity and air temperature exceed certain thresholds, and the "soil moisture" parameter has a strong influence on the irrigation period (Fig. 5). The output of the system is the "*irrigation period*" block. The output consists of an impulse signal that starts the irrigation system. Depending on this impulse signal, we will know when and for how long the irrigation process should take place.

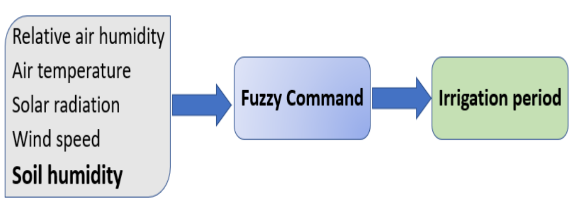

Fig. 5. Fuzzy Command

VI. CONCLUSION

IoT technology used in irrigation management systems of precision agriculture should meet water needs to increase crop productivity. The paper first outlined the main parameters to be monitored to obtain high efficiency of the automation system. A mathematical model was developed in MATLAB in which we used as input values the measured precipitation, perturbations, and as output data the humidity of soil. As can be seen in Fig. 2 and 3, the calculated model is valid since the evolution obtained based on the mathematical model is roughly the same as that obtained in the real simulation. Functions within the telemetry system ensure increased irrigation efficiency, both from the energy and agriculture point of view, by increasing productivity and reducing the risk of planting diseases.

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