Design of a Real Time Feedback Automation Irrigation System

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Abstract—This paper presents the design of a real time feedback control automated irrigation systems that consists of monitoring units, control units, irrigation pipeline valves, and a network of irrigation pipeline. The monitoring units continuously measure the soil moisture content in the irrigation blocks, and if the moisture content drops below a predetermined threshold for the particular crop under production, it sends a wireless message to the control units controlling the pipeline valves along the water flow channel, causing the control units to open the valves leading to the water source and commencing automatic irrigation. When the moisture content rises above a predetermined threshold for the crop, the monitoring units sends a wireless message to the control units, causing them to close the pipeline valves and cease automatic irrigation. An automatic irrigation system pipeline network optimization software has also been designed to plan, cost, and design the automatic irrigation system for a piece of land prior to installation.

Index Terms—Automated Irrigation System, Crop Moisture Requirement, Irrigation, Irrigation Software.

I. INTRODUCTION

Irrigation is the artificial application of a controlled amount of water to the soil through various systems of tubes, pumps, and sprays [1]. Four common types of irrigation are surface or flood irrigation, localized irrigation, Drip or micro-irrigation and sprinkler irrigation. For surface irrigation, water is distributed over and across land by gravity without the use of mechanical pumps. For localized irrigation, the water is distributed under low pressure through a piped network in a predetermined pattern and applied to each plant or adjacent to it. For drip irrigation, drops of water are delivered at or near the root of the plants to minimize evaporation and runoff [2]. For sprinkler irrigation, the water is piped to one or more central locations within the field and distributed in a high-velocity, high-volume spray by overhead high-pressure sprinklers or guns that may or may not be on moving platforms.

An automated irrigation system refers to the operation of the system with no or just a minimum of manual intervention beside the surveillance. Almost every system can be automated with the help of timers, sensors or computers or mechanical appliances [3]-[5]. Irrigation automation is justified where a large irrigated area is divided into small segments called irrigation blocks and segments are irrigated in sequence to match the discharge available from the water source [3]-[5]. There are six high-tech automation systems: Time based Systems, Volume based Systems, Open Loop Systems, Closed Loop Systems, Real Time Feedback Systems, and Computer based Irrigation Systems [6].

This paper presents the design of an automated real time feedback irrigation system in which soil moisture content, temperature and humidity are automatically measured every few seconds using moisture sensors. If the moisture in the soil falls below a minimum threshold for the agricultural crop in the land, the system sends a wireless message to the valves in the irrigation pipelines, including the valve controlling access to the main water source, causing the power supply to the valves to be altered, opening them and allowing water to flow into the land for crop irrigation. Soil moisture is continuously measured throughout the entire irrigation process. When the moisture level in the soil rises above a maximum threshold for the crop, the system sends another wireless message to the valves in the irrigation pipelines, altering the power supply to the valves to shut them and cease land irrigation.

II. MATERIALS AND METHODS

A. Materials

Software: Once a land section has been identified for automatic irrigation, the real time feedback installation for that particular land is designed and analyzed using an automated irrigation system pipeline network optimization software currently owned and patented by RACETT CANADA INC and RACVETT NIGERIA LTD. An image of this agriculture software is shown in Figure 2. The user inputs the area of the land to be irrigated, the type of automatic irrigation requested, and the crop being cultivated on the land. This information is utilized to calculate the number of irrigation blocks needed for optimum irrigation, the number of monitoring units and control units, and pipeline valves required, the length of irrigation pipeline needed, and the number of outlets or sprinklers needed (if any).

This information is also used to calculate the acceptable range of soil moisture content, outside of which the system would automatically turn on to provide irrigation. The irrigation layout for a 160 m by 160 m plot of land designed by the automated irrigation system pipeline network optimization software is shown in Figure 2. A default value size of 20 m by 20 m was set for a single irrigation block.
Fig. 1. Automated Irrigation System Network Optimization Software

Fig. 2. Irrigation Layout for a 160 m by 160 m plot of land with sprinkler irrigation using the Automated Irrigation System Network Optimization Software

These are the set of sensors that are used to determine when the automated irrigation system needs to be turned on. For water irrigation, the amount of moisture in the soil will be the primary measurement used in determining the threshold for switching on the system, as well as the humidity. Some of the sensors used in the automated irrigation system are shown in Figure 3.

Development Board: A development board will be required for the automated irrigation system to be able to autonomously detect the environmental data necessary to determine when land irrigation should commence or cease. The development board used in this system is the Arduino Mega.

Irrigation Pipes: There are several types of pipes used for irrigation. The most common is aluminum irrigation pipes. The diameter of the pipes selected for land irrigation depends on the availability of the water source and the size of the land to be irrigated.

Irrigation Pipeline Valves: Irrigation valves are placed at strategic locations within irrigation pipes to control the flow of water. By closing or opening these valves, the flow of water to the land can be turned off or on. They usually require a power supply of 12 V or 24 V. The power connection for the valves can be connected to the Arduino mega using relays to automatically alter the power supply to the valves, causing it to either close or open.

Irrigation Water Pump: A water pump is required in order to provide enough force to move the water from the water source to the land to be irrigated. This is usually achieved by connecting a water pump to water source and the irrigation pipes.

12V and 24 V Relays: Relays are electrical switches used to establish or break an electrical connection. 12 V and 24 V relays are used in the automated irrigation system to connect and control the power supply to the irrigation pipeline valves using the Arduino Mega.

B. Methods

The method of operation for the automatic irrigation system presented in this paper is shown in Figure 5.

Fig. 5. Operation of the Real Time Feedback Automated Irrigation System

The real time feedback automated irrigation system automatically and continuously measures the temperature, humidity, and moisture level in the soil using a monitoring unit that comprises of several sensors, an Arduino Mega, XBee Shield, and XBee Pro Module. Each valve in the

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irrigation pipeline is fitted with a control unit consisting of an Arduino Mega, XBee Shield, XBee Pro Module and a Relay to electrically control its power supply using the Arduino Mega. The water pump at the water source is also fitted with a control unit.

When the moisture level drops below a certain threshold, the system sends a wireless message to the water pump and the pipeline valves of the irrigation system, altering power supplies to activate them, causing water to flow through the system and water the soil in the irrigation block. When the moisture level rises above a certain level, the system sends a wireless message to the water pump and the pipeline valves in the irrigation system, altering the power supply to stop allowing water from the water source flow into the irrigation pipelines and into the soil in that particular block. The automated irrigation system can be applied to a single irrigation block requiring irrigation (Figure 6a) or multiple irrigation blocks with differing irrigation requirements (Figure 6b).

Figure 6b shows the real time feedback system for localized irrigation of multiple land sections or irrigation blocks. The land to be irrigated comprises of three irrigation blocks with grass, agricultural crops (tomatoes), and flowers (sunflowers) respectively. When moisture level in Block 1 drops below the minimum moisture level for grass, the monitoring unit sends a wireless message to Valves V1, and V2, as well as the control unit for the water pump, causing the power supply to both valves and the water pump to be altered, switching on the water pump and the valves and allowing water from the well to flow into Irrigation Block 1 only. When the measurement of the moisture sensor in Irrigation Block 1 rises above the maximum moisture level for grass, it sends a subsequent wireless message to Valves V1 and V2 and the water pump, causing the power supply to both valves and the water pump to be altered, closing the valves and the water pump, preventing water flow from the reservoir to Irrigation Block 1.

For Irrigation Block 2, when the moisture level drops below the minimum moisture level for tomatoes, the monitoring unit sends messages to Valves V1, and V3, to commence irrigation and then does the same thing to cease irrigation when the moisture level exceeds the maximum for tomatoes. For Irrigation Block 3, when the moisture level drops below the minimum moisture level for sunflowers, the monitoring unit sends messages to Valves V1, and V4 to commence irrigation, and when the moisture level exceeds the maximum for sunflowers, it sends another message to cease irrigation.

Figure 7a shows the real time feedback automated irrigation system for drip irrigation of a single irrigation block. Figure 7b shows the system for sprinkler irrigation of multiple irrigation blocks.

III. RESULTS

The automated irrigation system pipeline network optimization software assists farmers and users assists in determining which automated irrigation system will be most suitable for the land section they wish to perform automated irrigation. The optimization software allows farmers and users to know ahead of time how much it will cost them to irrigate any piece of land by providing the number of components that would be required for full automatic irrigation. For the example shown in Figure 1, a farmer wishing to irrigate a 160 m by 160 m plot of land with sprinkler irrigation would need 28 sprinklers, 64 monitoring units, 109 control units, 109 pipeline valves, and irrigation pipelines 2575 m in length for optimum irrigation of his or her land. The cost of irrigating the land can be calculated, as the cost of each component is known. Selecting the type of crop to undergo irrigation on the land allows the monitoring units to be programmed specifically for that particular crop’s soil moisture requirement (in this case, tomatoes). The minimum moisture threshold for commencing automatic irrigation and the maximum for ceasing irrigation is determined by the crop selected by the user in the irrigation software.

For the 160 m by 160 m automatic sprinkler irrigation
system, the software not only calculated the number of components required for optimal irrigation, it also designed the real time feedback control system for the land, laying out the irrigation pipelines over the specified land space, automatically dividing the land into irrigation blocks. A single irrigation block is set to a default size of 20 m by 20 m. However, this value can be modified if practical implementation of the system proves it to be necessary. The layout design allows for each irrigation block to automatically determine when it requires irrigation (based on the user-selected crop) and transmit its irrigation request to the valves controlling water flow to the block. The wireless sensor network between the control units in the irrigation valves and the monitoring units in the irrigation block is designed such that all control units along the water flow path from the water source to the irrigation block are instructed to receive irrigation control messages from the monitoring unit in that particular block. A control unit receives irrigation messages from only the irrigation blocks which require its valve to open or close in order to start or cease automatic irrigation. Because of this automated network, a farmer can practice multi-cropping on a single piece of land, with each crop receiving the correct moisture requirement for optimal germination and productivity.

Because the monitoring units are customized for different plants, they can be used to determine the optimal moisture requirement for various crops and plants. This data is currently not available in the literature. Future work includes the utilization of the monitoring units to determine and quantify the soil moisture requirement for various crops. Placement of the monitoring unit in the land to be irrigated may be crucial for accurate water supply to the crops. Larger land sizes will require a larger number of monitoring units. And since the moisture requirement for most crops have not yet been determined scientifically and experimentally, the monitoring units can be used extensively to measure, collect and provide this data for the agriculture industry.

IV. CONCLUSION

This paper presents the design of a real time feedback control automated irrigation systems that consists of monitoring units, control units, irrigation pipeline valves, and a network of irrigation pipelines to provide automatic irrigation to irrigation blocks. An automatic irrigation system pipeline network optimization software has also been designed to plan, cost, and design the automatic irrigation system for a piece of land prior to installation. Future work includes the construction and implementation of the system’s prototype for agricultural cultivation.

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