International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075, Volume-1 Issue-1, June 2012

Microcontroller Based Closed Loop Automatic Irrigation System

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Abstract*— In last few decades, electronics and communication have become an integral part of our lives, always expanding into new realms, to provide ways to do things in precise manner. With the recent developments in wireless networks especially regarding power requirements and cost, it has become possible to conceive a comprehensive model for precision agriculture. In this paper we present a closed loop automatic irrigation system along with the temperature and water usage monitoring. The system can be used in greenhouses as well as open fields. The real time values of soil moisture, temperature(useful in greenhouse cultivation) are wirelessly transmitted using Zigbee technology from field to substation which controls the state of the motor and irrigation valves according to the desired moisture levels set by the user. A flow sensor is also interfaced to the main water supply which continuously tracks the water applied to the field. All the information viz. temperature, current soil moisture level in field, upper and lower moisture levels to be maintained in field (set by user), motor status, water usage and flow rate are displayed on LCD.

Index Terms*— Automatic irrigation, Zigbee, closed loop, Wireless, Precision agriculture.

I. INTRODUCTION

India is an agriculture based economy. Most of the people depend on agriculture for their livings. But the per capita income of most of the Indian farmers is very low due to which lots of the farmers commit suicide. It is necessary to avoid the unnecessary or excess application of water, fertilizers etc. in the field so as to make farming more profitable which in turn will help India grow more rapidly and that too from grass root level. This paper aims to present a closed loop irrigation system which periodically monitor and control the various parameters of farming such as soil moisture, temperature, water flow etc., so as to optimize the application of various resources such as water, fertilizers etc. for maximum production. The system presented here makes the irrigation automatic with the use of low cost sensors and the simple circuitry, thereby making it a low cost product, which can be bought even by a poor farmer. The soil moisture level is one of the critical parameters of agriculture, which controls the quality of the crops grown in any type of field. The system monitors soil moisture and perform automatic irrigation management. Besides automatic irrigation the system also monitors temperature of greenhouse and water usage in irrigation. The system can be divided into two main blocks:

1) Sensor Module
2) Substation

The substation and sensor module communicate to each other via wireless Zigbee network as shown in Figure1.

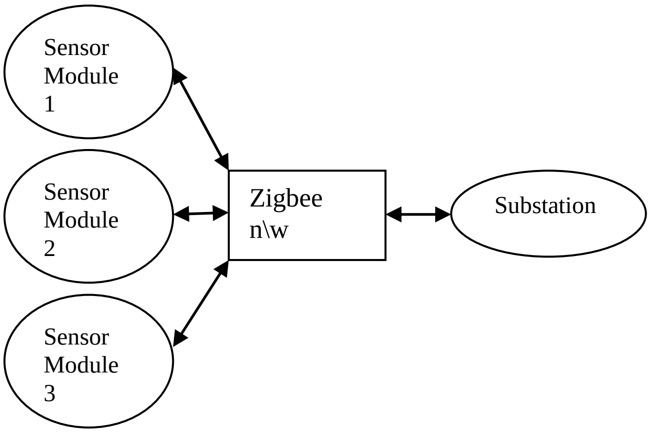

Figure1: Block Diagram of System

II. RELATED WORK

In [1] limitations of the conventional PLC based irrigation control systems is discussed and a new approach to automate the irrigation is presented. This system uses a Single Board Computer (SBC) using the Linux operating system to control solenoids connected to individual or groups of nozzles based on prescribed application maps. The main control box houses the SBC connected to a sensor network radio, a GPS (Global Positioning System) unit, and an Ethernet radio creating a wireless connection to a remote server. A C-software control program control the overall working of system. A wireless drip irrigation system using soil moisture sensors is presented in [2]. This paper describes an application of a wireless sensor network for low-cost wireless controlled irrigation solution and real time monitoring of water content of soil. Data acquisition is performed by using solar powered wireless acquisition stations for the purpose of control of valves for irrigation. The designed system has 3 units namely: base station unit (BSU), valve unit (VU) and sensor unit (SU). The system is energy efficient. Various technologies used for soil moisture sensors are discussed and compared and required characteristics of the soil moisture sensors are also discussed in [3]. Precision water-saving irrigation automatic control system by plant physiology is discussed in [4]. This project is one of the Olympic Games facilities projects, which takes standards of water plant physiologically need and soil water content as the basis.

Manuscript received on May 30, 2012.

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III. SENSOR MODULE

The heart of the sensor module is the Atmel AT89C2051 microcontroller to which the soil moisture sensor, temperature sensor and Zigbee module are interfaced. The soil moisture sensor used is watermark 200SS sensor. The Watermark 200SS [8] is a granular matrix sensor, similar to a gypsum block. It consists of two concentric electrodes embedded in a reference matrix material, which is surrounded by a synthetic membrane for protection against deterioration. A stainless steel mesh and rubber outer jacket make the sensor more durable than a gypsum block. Movement of water between the soil and the sensor results in changes in electrical resistance between the electrodes in the sensor. The electrical resistance is then converted to soil moisture potential with the help of interface circuitry. Watermark resistance (kΩ) to soil matrix potential (kPa) conversion is done using a non-linear equation developed by Shock et al. [9]

$$SMP= (4.093+(3.213k\Omega))/(1-(0.009733*k\Omega)-(0.01205*Ts))$$

where SMP is the soil matrix potential in kPa, kΩ is the sensor output, and Ts is the estimated or measured soil temperature in ^{0}C near the Watermark probe. SMP is inversely proportional to the soil moisture. Temperature sensor used is DS18S20 digital one wire temperature sensor [10]. It is low cost and easy to interface and require only one pin of the microcontroller to interface. The DS18S20 digital thermometer provides 9-bit Celsius temperature measurements. It has an operating temperature range of –55°C to +125°C and is accurate to ±0.5°C over the range of –10°C to +85°C. In addition, the DS18S20 can derive power directly from the data line (“parasite power”), eliminating the need for an external power supply.

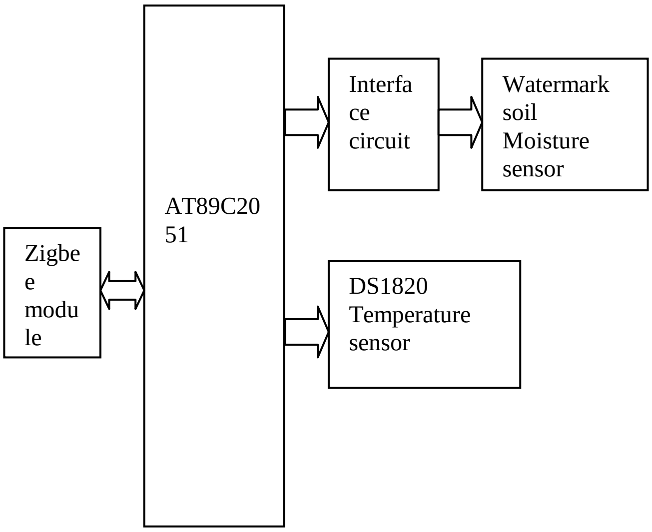

Figure2: Block Diagram of Sensor Module

The AT89C2051 microcontroller processes the information locally and sends current SMP and temperature serially to Zigbee module continuously. Figure2 illustrates the block diagram of Sensor module. Many sensor modules can be installed in case of large field.

IV. SUBSTATION MODULE

The substation module deploys AT89S8253 which has inbuilt EEPROM as shown in Figure3. The water flow sensor, pump motor and irrigation valves, LCD, switches (user input) and Zigbee module are interfaced to the microcontroller. The uC continuously receives the SMP and temperature data from different sensor modules via Zigbee module. Three switches (user input interface) are provided for the user or farmer to set the upper (HLSMP) and lower (HLSMP) moisture levels of soil (in terms of SMP) to be maintained according to specific crop and soil type. These levels HLSMP and LLSMP are stored in EEPROM so that even when power fails these values are not lost. The uC continuously compares the current SMP received from Zigbee module with the stored moisture levels LLSMP and HLSMP. Whenever the moisture level of field falls below the lower limit set by user the motor is turned ON and the valve corresponding to that part of field is turned ON. Valve will remain ON until the current SMP reaches the HL. Algorithm for motor and valve control is discussed below. If any of the valves is ON motor remains turned ON otherwise OFF.

Case1: Current SMP < HHSMP – Since the SMP is inversely proportional to moisture contents of soil, a higher value of SMP means dry soil and a lower value of SMP means wet soil. In the case we are discussing, soil is more wet than the prestored higher level of wetness. So the microcontroller turn off the valve in case it is ON, otherwise does nothing.

Case2: HHSMP < Current SMP < LLSMP - In this case soil moisture level in the soil is in desirous range and hence microcontroller keeps the valve state as it is , whether it is ON or OFF.

Case3: Current SMP > LLSMP - In this case soil moisture level in the soil is below the prestored lower level of moisture and hence microcontroller turn on the valve if it is OFF, otherwise keep it ON.

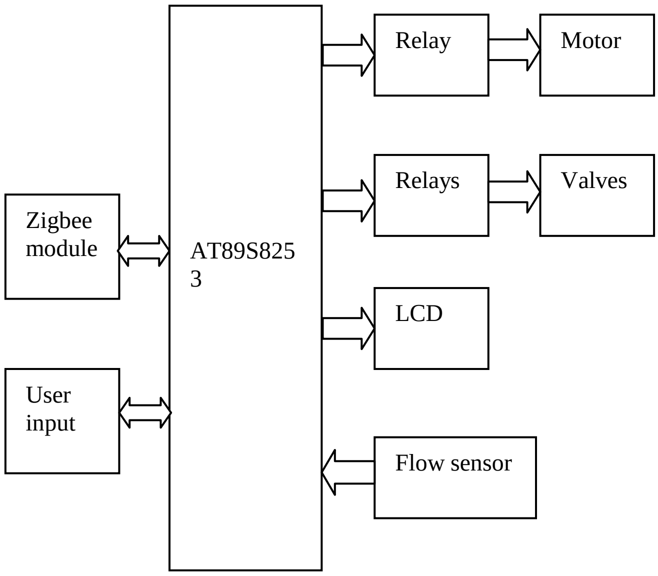

Figure3: Block Diagram of Substation

The flow sensor used in the system is FS-4400H from Savant electronics [11].

This sensor output digital pulses corresponding to the rate of flow of water through it. These pulses are counted to determine the flow rate of water as well amount of water that has passed through the sensor. As long as the motor is ON system will continuously updates the amount of water passed through pump. A 16×4 LCD is connected to the microcontroller, which displays the upper and lower moisture levels set by user or farmer (according to specific crop), current moisture level of soil, current temp in greenhouse, motor status and water usage. All the parameters are regularly updated to keep displaying real time values and performing controlling tasks. Nine relays are provided which are controlled by the microcontroller to on/off the main motor and eight irrigation valves corresponding to eight sensor modules.

V. RESULTS

The system was tested in field for five different crops namely: cabbage, cotton, potato, tomato, onion. The lower level of SMP (LLSMP) at which irrigation is started for these crops is shown in the Table1. The higher level of SMP (HHSMP) was set 20-25% of the lower level of SMP. The operation of motor and valves was tested for various cases and found to be perfectly accurate. The system was also tested for water measurement and the water reading was found to be accurate within ±0.5% of readings in various cases.

Table1: SMP at which to initiate irrigation for different crops

Crop	SMP (Kilo Pascal)
Cabbage	40 Kpa
Cotton	80-85 Kpa
Potato	40-55 Kpa
Tomato	50-70Kpa
Onion	30-40Kpa

VI. CONCLUSION

The closed loop irrigation system was developed and successfully implemented along with flow sensor and temperature sensor. Salient features of the system are: Closed loop automatic irrigation system, temperature and water usage monitoring. User can easily preset the levels of the moisture and is regularly updated about current value of all parameters on LCD display. In future, other important soil parameters namely soil pH, soil electrical conductivity will also be incorporated in the system.

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