Proceedings of the International Conference on Inventive Computing and Informatics (ICICI 2017)
IEEE Xplore Compliant - Part Number: CFP17L34-ART, ISBN: 978-1-5386-4031-9

Design and Implementation of an Automatic Irrigation Feedback Control system based on Monitoring of Soil Moisture

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***Abstract*— This paper deals with the development in agricultural activities like irrigation, soil temperature and moisture measurement using digital technologies and wireless sensors. Water is the heart of irrigation system and shortage of water is a growing issue for farmers. Water quantity needs to be checked for better productivity and sustainability of crops. Water regulation for different crops is different as insufficient or excessive water can be destructive for farming. An automatic wireless sensor based Irrigation Water Regulation support system is being developed. The proposed system estimates the water requirement for crops on the basis of soil moisture data gathered by several sensor nodes deployed in the field. Automation proved time and cost effective in a manner which is of great boon to the industry and as well as for entrepreneur in all the dimensions.**

Keywords— DTMF; GSM; induction motor; irrigation; soil moisture sensor

I. INTRODUCTION

Wireless technologies have been growing fast in recent years. These technologies are classified depending on the range of communication between sensor nodes. For shorter distances Infra red (IR) sensors based on light, point to multipoint communication Wireless Personal Area Network (WPAN), long distance communication GSM/GPRS/DTMF and Bluetooth, Zigbee can be used. This wireless sensor based system monitors the water requirement for a particular crop continuously and sends the feedback to the main system which controls the water flow [1]. This system is intelligent enough to send the signals on mobile of the farmer to control the irrigation time and water flow. Adequate water flow and irrigation not only maximize the efficiency and production but also saves the time and labour of farmers. The sensors developed for measurement of soil moisture can also measure temperature of the soil to solve the problems related to soil for a particular crop.

The major challenge faced in dry and semidry areas of agricultural land is the water regulation for crops. Recent technologies are trying to benefit and solve these problems [2].In some areas even water flow requirement is such a big issue that farmers are facing economical as well as sustainability issue.

Sensors are used to improve the decision making capability of the system by sending feedback. Soil moisture sensor senses the environmental and soil conditions which can be sent back to the system for efficient performance. The systems developed so far in this context are wired based data loggers which are costly and have an installation issue in real time interface. This system measures information of soil moisture content stored in it and sends it to the main system with the help of microcontroller and other electronic devices [2].

The research work of this paper is related to the development of agricultural activities like irrigation, soil temperature and moisture measurement using digital technologies and wireless sensors. An automatic wireless sensor i.e. soil moisture based Irrigation Water Regulation support system is being developed in this work. The proposed system estimates the water requirement for crops on the basis of soil moisture data gathered by several sensor nodes deployed in the field. The components and technology used in proposed system is explained in section 2.The section 3 illustrates the implementation of proposed system. At the last section 4 and 5 covers the results and conclusion part.

II. COMPONENTS AND TECHNOLOGY

The proposed system is consisting of Microcontroller unit, Analog to Digital converter, Induction motor, Soil moisture sensor, Temperature sensors and DTMF receiver.

A. Microcontroller Unit

Microcontroller is a device used in place of processors where the requirement is limited and data rate required is a not big issue. The 8051 microcontroller has been used as it is low cost, low power and high performance unit. It allows a feature of on chip flash programmable memory which makes it easier to be reprogrammed within the system. This also makes it easy to interface different sensors and input output devices with 8051.

B. A to D Converter

Analog to Digital converter is a device which is used to convert the output of the sensor which is analog in nature as microcontroller understands digital data. ADC0804 is a converter which converts one analog signal into 8 bit digital output which is being sent to 8-bit microcontroller. This is a clock driven chip which decides the time required to convert the analog value into digital value.

C. Induction Motor

Induction motor is preferred over dc motor because it has low cost, ruggedness, smaller size and weight. Apart from the simple design it can operate in dusty and explosive environment because the brushes are not being used. Therefore there is no possibility of sparking which results in extremely reliable, low maintenance operability. Contactors along with relay card are used to switch on and off the motor.

D. Soil Moisture Sensor

Soil moisture sensor is a device which measures the water content of the soil. More is the water content in soil lesser is the water flow requirement. Some capacitance based sensors are developed in recent years which are also known as frequency domain sensors. Another sensor, the neutron moisture gauge, utilizes the moderator properties of water for neutrons [3, 4]. Cheaper sensors are based on two electrodes measuring the resistance of the soil. Sometimes this simply consists of two bare (galvanized) wires, but there are also probes with wires embedded in gypsum.

1) Different sensor constructions

*a) Iron nails used as probes:*The nails are rusted as a result of water present in the mixture. It also became difficult to maintain an appropriate distance between the heads of the nails given the small diameter of the pipe. The mixture of Plaster of Paris and water resulted in a brittle solid mass after drying because of an inappropriate amount of water in the mixture prepared. Fig. 1 represents the Sensor with iron nails probes.

Fig. 1. Sensor with iron nails probes

b) Copper electrodes used as probes: Fig. 2 represent the Sensor with Copper probes.Copper probes corroded due the presence of oxygen in air to form a black coloured copper patina which gradually turned green with time. The black colour compound formed was copper oxide.

$$2Cu + O_2 \longrightarrow 2CuO$$
$$\text{Copper + Oxygen} \longrightarrow \text{Copper Oxide} \quad (1)$$

Hence, the results consistently varied with time due to varying resistance of copper electrodes.

Fig. 2. Sensor with copper probes

c) Aluminium conductors used as probes: Sensor with aluminium probes is shown in Fig.3.The sensor was successfully constructed and calibrated.

Fig. 3. Sensor with aluminium probes

E. Temperature Sensor (LM 35)

Temperature sensors are devices which act as transducers to sense the temperature and convert it to voltage proportional to temperature in Celsius. LM35 is a sensor used in this system which has low output impedance, linear output, and precise inherent calibration which makes it easy to get it interfaced with ADC and Microcontroller 8051.

F. MT8870 DTMF Receiver

A receiver is used in this circuit to receive the data from different from 16 Dual Tone Multiple Frequency (DTMF) tone pairs and convert the same into a 4-bit code which can be easily read by the microcontroller. This receiver is DTMF MT-8870 18 pin chip which has in built Differential amplifier with gain settings provided internally, clock generator with modifiable guard time and interface bus for communicating with external input output devices. It is a low cost receiver which uses 3.5 MHz crystal frequency oscillator. The DTMF receiver is easily compatible with MT8870/MT8870C-1 which is an advantage of using it.

G. Dual Tone Multiple Frequency (DTMF) Technology

Dual Tone Multiple Frequency is a chip which is widely used for analog communication in telephone lines to transmit and receive the data between transmitter, receiver handset and switching center. The push buttons on mobile provides twelve DTMF signals with different frequency combinations of low and high frequencies ranging from 697 Hz to 1477 Hz. Table 1 shows the frequencies used for each signal:

TABLE 1. DTMF keypad frequencies

Frequency	**1209 Hz**	**1336 Hz**	**1477 Hz**
697 Hz	1	2	3
770 Hz	4	5	6
852 Hz	7	8	9
941 Hz	*	0	#

The table 1 describes the frequencies corresponding to each button pressed every time. Every key pressed produces two different tones with different frequencies and produces a resultant frequency signal ranging between two selected frequencies. This resultant frequency signal is called Dual Tone Multiple Frequency.

III.MPLEMENTATION OF PROPOSED SYSTEM

A. Block Diagram and Circuit Explanation

A Circuit is made which provides continuous DC power supply to the microcontroller as well as any other electronic device/IC being used in the entire circuit. 220V ac is converted to 24V ac by a step-down transformer [4, 5]. A diode bridge rectifier is used to convert 24V ac to 24V dc and then the Voltage regulator (L7805) brings down the voltage to 5V DC. Temperature sensor along with ADC 0804 is interfaced with the microcontroller to measure the temperature and give the digital input to the microcontroller. LCD is also interfaced with the microcontroller and when the power supply is turned ON, the LCD illuminates and displays the room temperature at that time e.g. “TEMP: 20C”. The block diagram of the proposed system is shown in Fig.4.

Soil moisture sensor measures the water content in the soil and its resistance varies accordingly and hence the output voltage too. The output of the soil moisture sensor is connected to a microcontroller pin. In dry state, the resistance of soil humidity sensor is approximately 1.7M ohms and in the wet state i.e. when moisture is present the resistance drops down to 0.7M ohm. The voltage across the sensor in the dry state (0% volumetric water content) is 1.9V and in the wet state is 0.1V (50% volumetric water content). This voltage signal across the sensor is given to the microcontroller pin via an ADC 0804 and the microcontroller using this digital equivalent of the signal controls the duration of operation of the induction motor through the program fed into it. This induction motor is interfaced with the microcontroller via the relay card and the contactor which is connected to the motor starter. When the motor is turned on, “MOTOR ON” is displayed on the LCD and when the motor is OFF, the LCD displays “MOTOR OFF”.

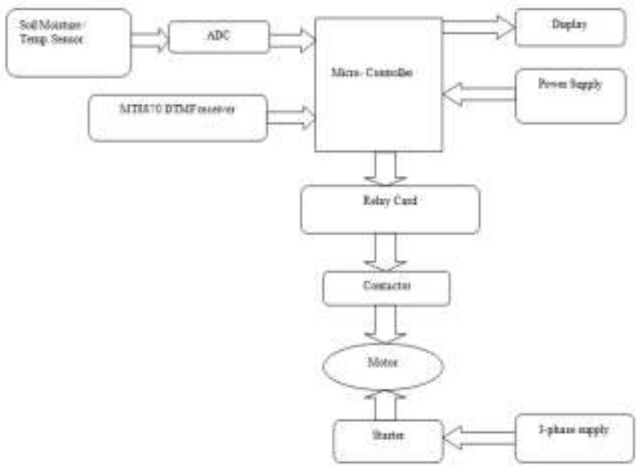

Fig. 4. Block diagram of system

B. Modeling of SensorParameters

The input parameter which is being sensed by sensor is moisture of the soil. The physical quantity (moisture) is being converted into electrical quantity (resistance) by the following two methods [6].

a) Volumetric water content method

- Take a known volume of dry soil in a container.
- Add a known volume of water in it.
- Insert the sensor into the soil and note down its resistance.
- For each epoch, note down the parameters measured in the above steps.
- Repeat the above steps while increasing the amount of water added in Step 2.
- Calculate soil volumetric water content (in %) by the formula given in equation 2:

$$\frac{\text{Volume of water (in cc)} \times 100}{\text{Volume of Dry Soil (in cc)}} \tag{2}$$

Volume of soil used = 500 cc

TABLE 2 Calibration table for volumetric water content method

No	Volume of water (in cc)	Volumetric water content (in %)	Resistance of sensor (in Mohm)
1	25	5	1.7
2	50	10	1.3
3	100	20	1.2
4	150	30	1
5	200	40	0.9
6	250	50	0.7

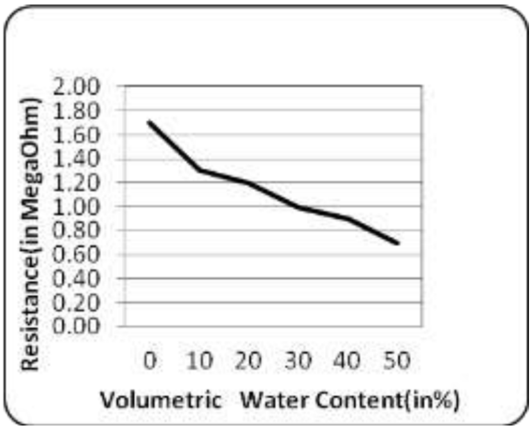

Fig. 5. Volumetric water content calibration graph

b) Mass percentage method

- Take a microwave safe container and note down its weight.
- Take some dry soil in a container and weigh the container.
- Insert the sensor into it and note down its resistance.
- Take a fresh sample of soil and add some water into the soil and note down the sensor resistance.
- Weigh the container after adding water.
- Heat the container in microwave for 5 minutes at 800W. Note down the weight of the container now. The difference in the weight of the container before and after gives the weight of water present in the container.
- Repeat steps 4 to 6 for different amounts of water added.
- Calculate mass percentage of water by equation 3:

$$\frac{\text{Weight of Water} \times 100}{\text{Weight of Dry Soil}} \quad (3)$$

Where

Weight of Dry Soil = Weight of (container + soil) after putting the container in microwave - Weight of the container

Weight of Wet Soil = Weight of (container + soil) before putting the container in microwave - Weight of the container

Weight of Water = Weight of Wet soil - Weight of dry soil.

TABLE 3 Calibration table for mass percentage method

Weight of Soil+Water (in gm)	Weight of dry soil (in gm)	Water Content (in %)	Resistance of the Sensor (in Mohm)
120	120	0	2.3
140	110	27.27	1.8
120	90	33.33	1.4
180	120	50	1.1

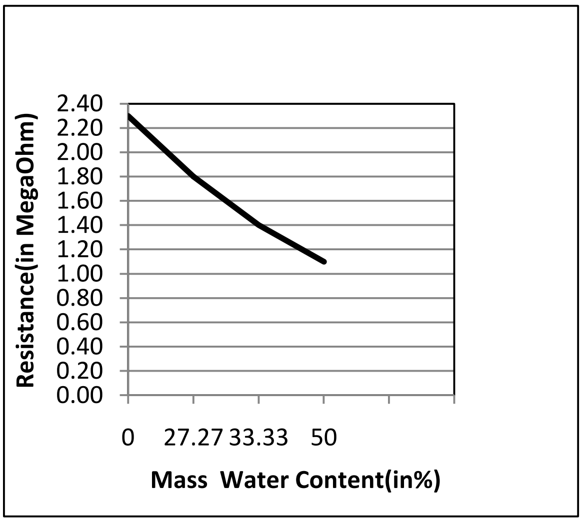

Fig. 6. Mass percentage calibration graphs

IV. RESULTS

After designing and implementing the proposed system, the following results were observed. Whenever moisture level of the soil goes down, it is sensed by the soil moisture sensor and the duration of motor operation is controlled depending upon the moisture content of the soil [7]. The calibration table gives an accurate estimate of the resistance of sensor pertaining to the different values of the volume of water in the mass percentage method and the volumetric water content method as well. Thus it possible to have a precise calculation of the weight of water from the weight of wet soil and the weight of dry soil. Also, the analysis for the mass percentage of water helps to have an adequate water regulation for crops and overcomes both the adverse conditions of exuberance and scarcity of water at different locations in a field. So we deduce that the incorporation of automation in the field of agriculture improves the reliability, sustainability and operability of the field. In controlling the moisture, the action taken by the microcontroller is tabulated in the table 4.

Testing results in table 4 may vary according the size of the field. It was observed that the proposed system led to remarkable savings in use of both water and electricity. This not only saves the money of the farmer but also protects the fertility of the soil as the proposed system reduces leaching of the soil to a great extent [8, 9].

The proposed system is being validated on commercial field located in Punjab, Landran.

TABLE 4 Testing Results

S. No.	Type of Crop	Moisture Content (%)	Duration of Motor (mins)
1	Wheat	0-35	10-Jul
		35-65	0-7
2	Cotton	0-35	10-Jul
		35-50	0-7
3	Grains	0-40	8-May
		40-50	0-5
4	Barley	0-45	6-Apr
		45-50	0-4

V. Conclusion & Future scope

The proposed soil moisture sensor based automated irrigation system is being developed using wireless sensors. The proposed system estimates the water requirement for crops on the basis of soil moisture data gathered by several sensor nodes deployed in the field. It is concluded that the proposed system led to remarkable savings in use of both water and electricity. The design can be further improved by attaching computer to the system as RS232 is given in the circuit. In case there's an error in the system, the farmer can be informed by interfacing the system with DTMF Transceiver and hence place a call on the farmer's mobile number. Also GSM module can be used to send a message to the farmer in case an error occurs.

Acknowledgement

We would like to acknowledge the support and cooperation from staff of UIET for helping us in every possible way.

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