Analysis of Soil Moisture Sensors

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Abstract - **This paper gives a comparative analysis of measurement of soil moisture using resistive soil moisture sensors of different dimensions. Soil moisture sensing probes of different dimensions are used to study their response towards different levels of moisture content. A comparison of characteristics of the sensors like response, sensitivity, stability over different ranges of soil moisture content is done using a microcontroller driven platform. The effect of dimensions of the copper strips on the characteristics of the sensing probe is studied which will help in choosing the appropriate probe in soil moisture measurement applications of varying ranges of soil moisture level**

Keywords — ATMEGA328, Microcontroller, Arduino uno, ADC, USB, resistive soil moisture sensor, capacitive soil moisture sensors

I. INTRODUCTION

Soil moisture is an important parameter required for the growth of crops [1]. Different crops need different range of soil moisture so that it can absorb the required amount of water and nutrients necessary for the growth of crops. So for better yield of crops the measurement and monitoring of soil moisture is required regularly in the field of agriculture [2]. Research has been done to build such systems where soil moisture is being attempted to be measured and water management in soil irrigation can be done effectively [3]. The most important factor that decides the selection of a soil moisture is cost and accuracy [4]-[5].There are many commercially available soil moisture measuring devices having high accuracy and stability but are costly. The resistive sensors are less costly, easy to maintain and install compared to other soil moisture sensing devices. Again the requirement of soil moisture is different for different types of crops [6]. Some plants need root level monitoring of soil moisture whereas some crops does not. So the dimensions of the sensor also vary for different levels of soil. So a study of soil moisture measurement is done using low cost resistive sensors and capacitive sensor and a comparison is drawn between resistive sensors of different dimensions to find the best one as shown in figure 2 a..

II. RESISTIVE SOIL MOISTURE SENSORS OF DIFFERENT DIMENSIONS

Further study was done to see the effect of physical dimension of soil moisture probes and its characteristics. The resistive sensor probes were constructed and the moisture is measured using all the probes along with commercially available capacitive and resistive sensor. Soil moisture sensing circuit is designed such that for lower moisture content of the soil, the voltage output of the sensing circuitry is higher and as the moisture content increases, output voltage of the sensing circuit decreases [7]. The plot between the output voltage of the sensor module and its corresponding moisture value gives the comparison of the characteristic behaviour of each sensor.

Four soil moisture probes are being constructed of different length, width and separation between the copper strips as shown in figure 2(a). A copper plate of 20cm x 20cm is taken. Then the sensor probes are drawn on it of required dimensions. The area where copper plating is required is coloured. Then the etching process is carried out where the board is dipped in a solution of Ferric Chloride. The board is dipped in the solution for half an hour constantly moving the board in the solution. Then the board is cleaned with a spirit or thinner to get the copper coating. It is seen that the copper is retained in the painted regions and gets removed from all other areas. After that the probes are cut as per the requirement and are connected to the signal conditioning electronic circuitry. The sensing circuit is designed such that it gives a higher output voltage for lower moisture level and the output voltage decreases with the increase in the moisture level of the soil. An experiment is carried out where the soil moisture measurement is done with five numbers of resistive sensors of different length and width and in addition, a capacitive sensor as shown in the figure 2(b) is taken for reference. A comparative analysis is done. Five resistive sensor probes R1-R5 having different dimensions as shown in table 1 are considered for measuring soil moisture.

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Table 1: Resistive soil moisture sensors

Sl.No.	Name of Sensor	Length of the probes (cm)	Width of the probes (mm)	Distance between probes (cm)
1	R1	15cm	3mm	1cm
2	R2	15cm	3mm	2cm
3	R3	15cm	6mm	1cm
4	R4	5 cm	6mm	2cm
5	R5	5cm	3mm	1cm

An analysis is done on the soil moisture sensors in a given soil sample. The system block diagram is given in figure 1.

III. SYSTEM DESCRIPTION

A. Block diagram

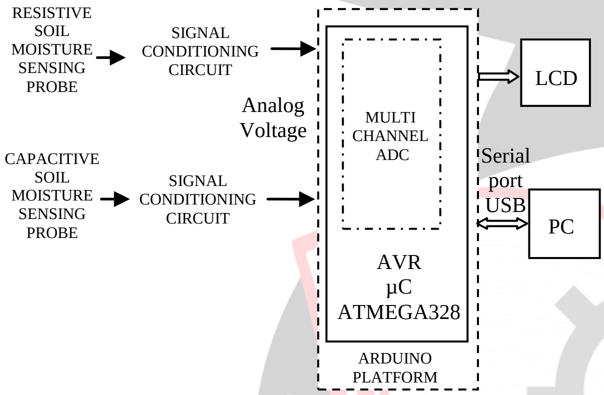

Fig.1: Block Diagram of the system

B. Sensors

Fig. 2 (a): Resistive soil moisture sensors of different dimensions

Fig. 2 (a): Capacitive soil moisture sensor

C. ArduinoUNO board

The **Arduino UNO** is a microcontroller board that uses ATmega328. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, reset button and contains everything required to support the microcontroller. It is connected to the PC with a USB cable to display the data on the PC. The Atmega16U2 is programmed as a USB-to-serial converter. It is an open-source platform and is easy-to-use hardware and software. The microcontroller senses the parameters in the environment by receiving inputs from the respective sensors and converts these inputs into respective values of temperature, relative humidity and soil moisture. These data are then displayed on the LCD as well as on the PC.

IV. METHODOLOGY

Here the soil moisture is calculated using gravimetric method [8]. At first a sample of soil is oven dried to remove the moisture content from the sample and weighed. The five sensors are then inserted into the soil sample as shown in figure 3 and figure 4. The sensors sense the soil moisture and give an analog output voltage that is proportional to the moisture content of the soil. The corresponding voltage is noted down that is considered to be the one corresponding to zero moisture.

Conversion of soil moisture into voltage:

Microcontroller ATMega328 that is used in the system has a 10-bit ADC. Reference voltage applied to the ADC is 5V.

$$V_o = (5/1024) * A_{adc},$$

where A_{adc} is the integer value corresponding to the analog voltage output of the sensor after amplification by the signal conditioning circuit, V_o is the voltage measured by the microcontroller.

Thereafter a certain quantity of water about 3 ml is added to the dried sample and weighed. Corresponding analog voltage outputs of the sensors are also noted down. This process is repeated up to a moisture value of 35%. As the moisture increases, the sensor gives a decreasing analog output voltage proportional to the moisture content. These voltages are then fed to the microcontroller ATMEGA328 as shown in figure 1 that converts these voltages to their respective moisture values and then displayed [9]-[12].

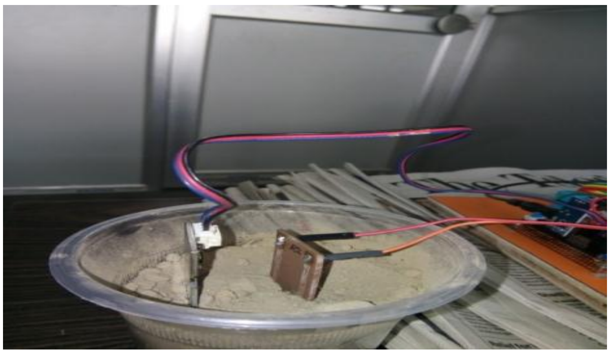

Fig. 3: Moisture measurement of the soil sample

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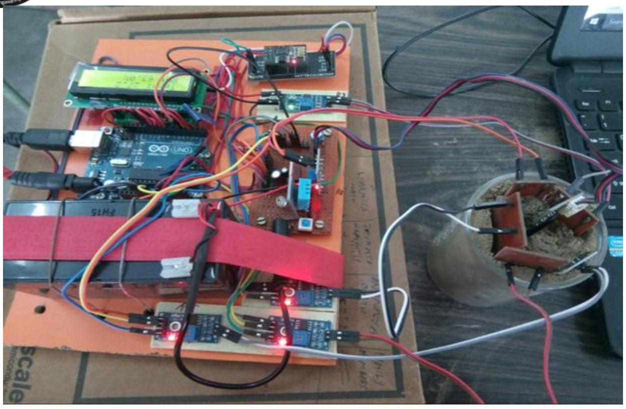

Fig. 4: Moisture measurement of the soil sample

V. RESULTS AND OBSERVATIONS

The behavior of all the sensors with soil moisture is shown in figure 5.

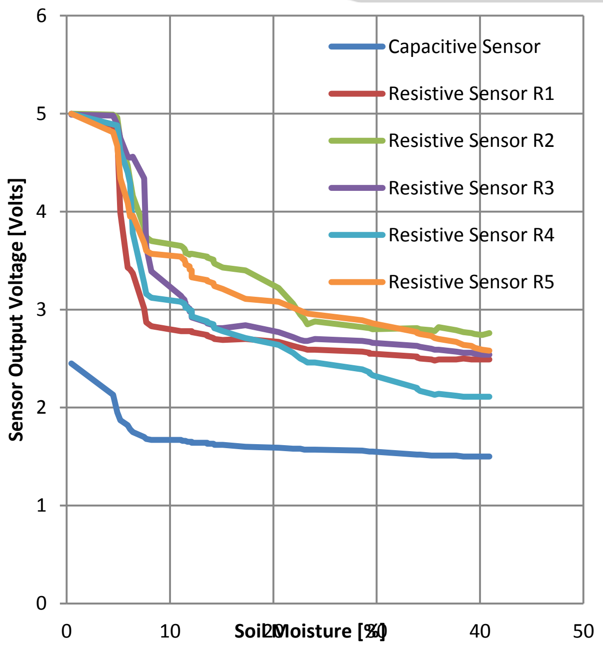

Fig.5: Comparative analysis of sensors of different dimensions

For all the probes, it is observed from figure 5 that the response to low level of moisture less than 5% is slow. When the moisture increases beyond 5%, there is a sharp decrease in output voltage with moisture. It is seen that time required to respond to change in soil moisture is less for resistive sensor compared to the capacitive sensor. Thus the resistive sensor is seen to be more sensitive than the capacitive sensor.

Observations:

1. Sensors R1 and R2 have same length, same copper thickness but the separation between the probes is different. It is seen that more is the gap, less is the conductivity and hence less is the sensitivity. Slope of R1 is more than the slope of R2. For same value of moisture the voltage output of R1 is less than R2 along the entire range.
2. Sensors R1 and R3 have same length but difference in thickness of copper strip. It is seen that the difference in thickness does not make much of difference because the difference in electrical resistance of the probe will be in the order of few milli ohms.
3. Sensors R1 and R5 have same thickness but different lengths. It is observed that the slope of R1 is more than R5 for moisture level up to 15%. This is justified by R1 that has a greater length than R5. With increase in length of the probe the sensitivity increases. For moisture level above 15%, voltage output of R1 having a greater length is less than R5.
4. For R4 that has double the thickness of the copper plate than R5 and double the separation between the two probes, the slope changes in the same manner. But for all values of moisture, the voltage output of R4 is less than R5. This is because the thickness of the copper strip of R4 is more than R5.

To study the repeatability for the resistive sensors (R1-R5), output voltage response with change in soil moisture is noted for a certain range from 0 to 28%. The experiment is repeated three times for the same soil sample with the resistive sensors. 17 data sets are taken, with 3 data in each set. Coefficients of variations are calculated for each data set for the resistive sensors.

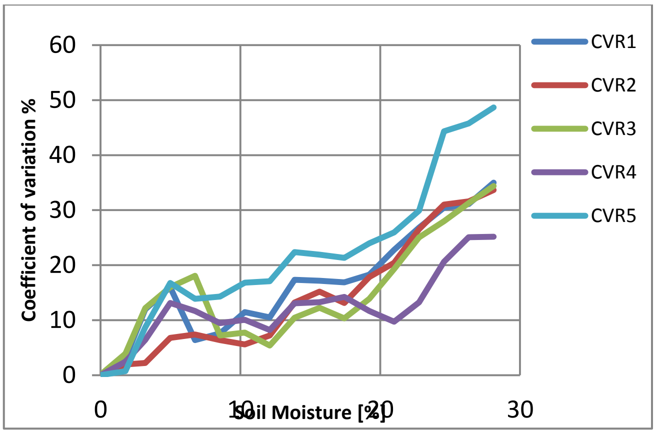

Fig.6: Coefficient of variation of resistive sensors

Referring to figure 6, it is observed that variation of results of soil moisture measurement given by all the five resistive sensing probes under consideration is lower for lower value of soil moisture. It increases with increase in soil moisture for all the sensors. For soil moisture in the range of 5% - 20%, the variation remains within 20% for all the sensors and thereafter starts increasing with increase of moisture. For sensors R1, R2 and R3, whose length are same, the variation changes in the same manner. In comparison variation for sensor R4 is lesser and is within 15% for moisture value up to 23%. Maximum value of variation is also less for R4. Thus comparing the coefficient of variations for the five sensors, R4 has lesser variation and gives a better figure of repeatability.

VI. CONCLUSION

For all types of probes it is seen that for lower values of moisture till 15%, slope is more. This indicates that up to

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15% of moisture level the change in voltage per unit change of moisture is greater. As the moisture level increases the slope decreases.

It can also be concluded that for resistive probes, increased width, lesser separation between the copper strips, brings a greater effect in its overall performance in terms of sensitivity and uniform response over wider range of moisture level.

In terms of repeatability, it is seen comparing the coefficients of variations of all the sensors that differs by physical dimension that width of the copper strips have greater effect compared to length in achieving better repeatability that have lesser variations in measurements. For all sensors, variation in measurements is lesser for lower soil moisture and it increases with increase in soil moisture.

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