ELECTRICAL CONTROL OF SOIL MOISTURE CONTENT

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ABSTRACT

Two-electrodes of moisture sensor is proposed in this work. This sensor overcome the problem of electrical control of soil moisture affected by salts, while this can not be accomplished by other types of sensors. The moisture content is transformed to resistance measurement, which is translated to a computer as volt value by transmission circuit. Obtaining the sensor input/output characteristics does the investigation of the soil moisture sensor. A comparison between the two-electrode sensor and ELE in salty soil was carried out. Soil moisture content is established in real time closed loop control, where the feed forward path is composed of relay element; the feedback path consists of a moisture sensor followed by a moisture transmitter. The ON-OFF moisture control and moisture control system identification is established via personal computer. The two-electrode moisture sensor type is very simple and cheap. The field experiment indicates that the major advantage of this sensor can be used in widely salty soil.

INTRODUCTION

Till now most of the irrigation methods established in farms are based on irrigation scheduling (Sammis-1990, Walied-1990, Tim Hess-1996 and Mohan-1996). But the new trend is based on feedback system, to determine precisely water required by the plants. Thus, soil moisture control becomes useful to establish self-control irrigation systems. As a result, water and plants are protected.

Many industrial processes are controlled applying ON-OFF controllers, which allows simple and straightforward behavior. This is done to get a fast, simple, cheap controller and also to obtain acceptable time response. On the other hand, it is obligatory to use this type of controllers when the final control element does not operate in a continuous or an analogue way. To fulfil such controller, only two parameters must be predetermined for the given process, the maximum and minimum values of moisture were established. Soil moisture content control is then established in real time by an ON-OFF closed loop control system, where the feed forward path is composed of a relay element, cascaded by the feedback path which consists of a moisture sensor followed by a moisture transmitter.

The main purpose of soil moisture sensor is not only to obtain good measurements, but also to perform a suitable feedback signal to the computer.

MATERIALS AND METHODS

System Component:

The system is installed in Buraydah City, Gassim area, KSA. The two greenhouses were constructed; the first is a fully controlled fiberglass of dimension 9 m x 16.5 m. Its air is conditioned by a 1.5 HP suction fan and a cooling pad of 6 m x 2.5 m and 6.0 cm thickness. The cooling pad is watered by a pump of 0.5 HP with out let diameter of 1.25cm. The second greenhouse has plastic cover and with the same dimensions of the first one. A 1.5 HP of 40 bar rated pressure pump establishes the irrigation soil. The irrigation is made through an irrigation network using tubes including emitters (4 l/h). It is activated using an ON-OFF solenoid valve of 12.7-mm diameter. Both irrigation pump and solenoid valve are driven by two Solid-State Relays (SSR) of 25 Amp and 5 Amp respectively. A personal computer relays by means of measurement and control card (Fig 1).

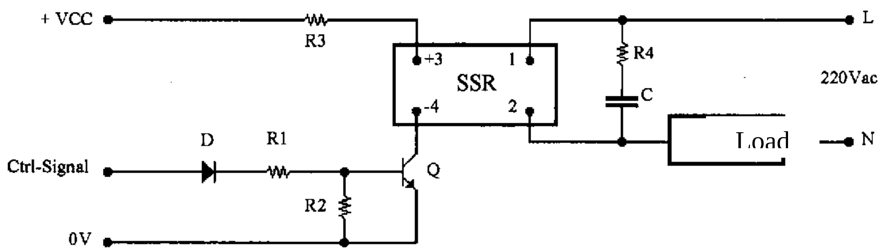

Fig 1: The solid-state relays (SSR) circuit diagram.

The Sensors of Moisture Content:

The main purpose of soil moisture sensor is not only to obtain good measurements, but also to perform a suitable feedback pass through the sensor signal to the computer. Many attempt were carried out to test the sensors in market, a comparison is made between three of soil moisture sensors. The two-electrode sensor is found to optimum within the present work, so it can sense the salty moisture for the range of 0 % to 35%.

After studying the types of moisture sensors existing in the markets, two types of soil moisture sensors exist. The first one is the type moisture sensor. A double “E” letter of copper metal are arranged and fabricated by chemical etching as printed circuit board fabrication (Fig.2). Then copper is coated by Gupstium material to obtain a good contact with the soil.

The second type is the ELE moisture sensor, which is fabricated by an American Company, specialized in environmental measurements. The construction of this type of sensor is found in ELE catalogue (Abou-zalam and Ismail,1999). The two sensors just mentioned are tested and excluded because, if the content of salt increases in the water or in the soil, the sensor gives wrong measurement due to short circuit. In order to overcome all of the above problems, a third proposed sensor type is used.

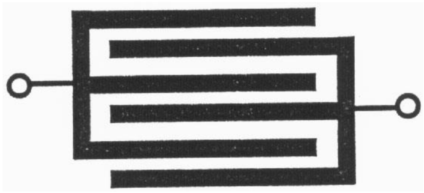

Fig. 2: The “ E” sensor of soil moisture content.

Designing two electrodes from copper does the third attempt. The two copper rods are mechanically coupled using plastic material to form two electrodes. The dimensions of the designed electrodes and the distance between them are indicated in Fig (3).

Three shapes and arrangements of the two-electrode moisture sensor can be proposed according to the required examples are:

a- Measurement of soil moisture in a wide area of soil.

This requires that the two electrodes of the sensor be placed at the desired distance from each other as shown in Fig. (4-a).

b- Measurement of soil moisture in the depth of the soil.

It is desired to use long electrodes, covered by a plastic material to isolate and make the contact at the depth of soil (Fig.4-b).

Measurement of soil moisture in the wide and in the depth of the soil. This arrangement represents the previous two cases. In this case two different sensors size are placed at a desired distance from each other, one long coated by a plastic material, and the other is a short one Fig. (4-c).

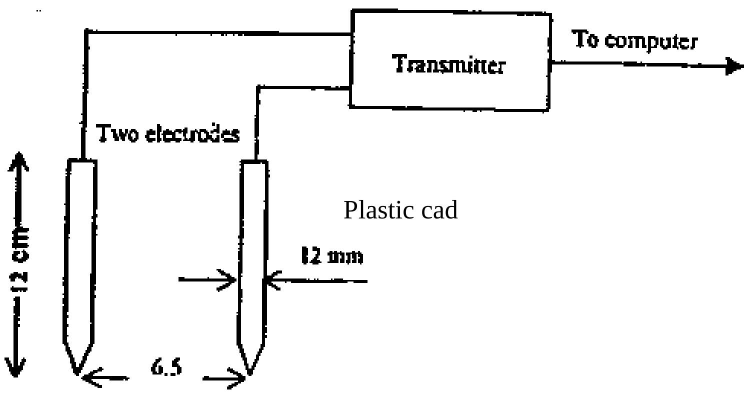

Fig. 3: The two-electrode sensor.

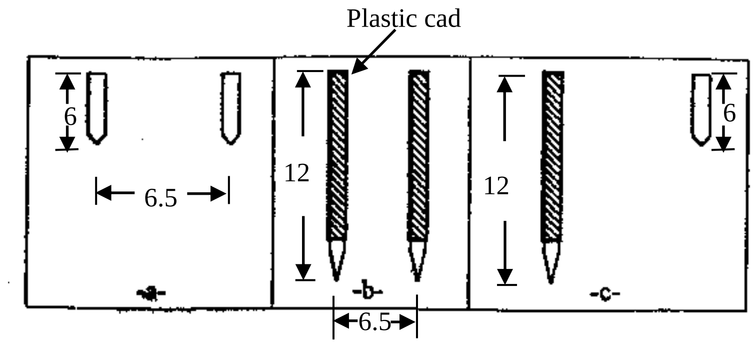

Fig. 4: Different shapes and arrangements of the two-electrode sensor.

Transmitter Circuit:

The moisture content acts as a variable resistance, so function looks like a thermal-resistance in the case of temperature measurements. The concerned moisture content ranges from 0% to 28.4% and is transmitted through a designed transmitter to give the voltage range from “Zero V” to “5V”. The transmitter contains two cascaded circuits (Fig.-5). The first circuit is a Whetstone bridge that is calibrated to obtain zero output voltage (i.e., zero soil moisture) at balance. The second is a “DC” amplifier with variable gain and ability of offset adjustment. The designed transmitter is calibrated in the laboratory and in the field, considering the wire resistance, caused by the long distance between the sensor and the transmitter (about 15 m). This is done to obtain very accurate measurements.

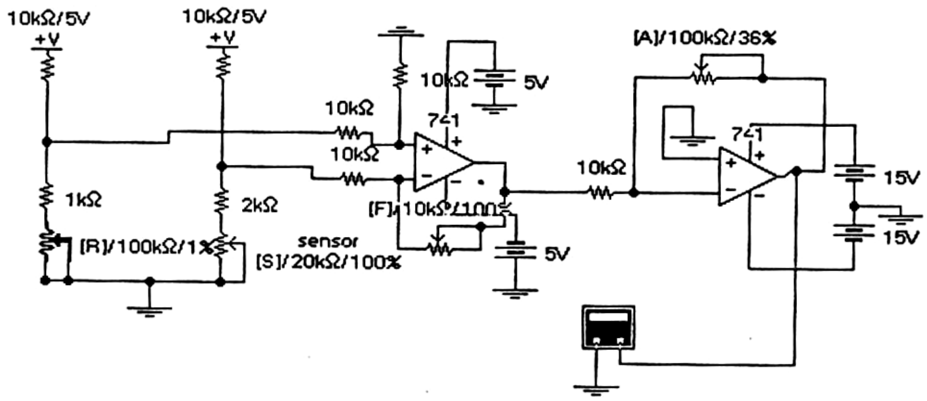

Fig. 5: Circuit diagram of transmitter.

Soil Analysis and Sensors-Transmitter Calibration:

A sandy soil, which is taken form the greenhouse ground, is analyzed in the King Saudi University, Soil and Water Laboratory, Qassim branch, KSA. The soil specification is indicated in table (1). From the table it is clear to notes that, the set point of the controller must be located between the wilting point (6.9%) and the field capacity (28.4%).

Table 1: Some physical and chemical soil-characteristics.

PH	EC, Mmoz/cm	HCO_3^-	CL^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	Phas (ppm)	K^+ (ppm)	F.C %	w.p %
7.31	15.93	1.14	98.5	61.66	67.5	2.1	91.7	18.6	412	28.4	6.9

In order to study the characteristics of the two-electrode sensor, the ELE sensor is chosen to make the comparison between the two sensors. Each of two sensors is connected to the transmitter circuit. Many soil samples of different moisture content (from 0% to 28.4%) are prepared to obtain good calibration (Colman and Hendrix, 1949). The zero moisture content of soil is obtained by applying the soil to a temperature of 105 c^o for 24 hours. Many moisture content samples are obtained by adding a precise quantity of water, for the required moisture. The two sensors are immersed in the soil samples until the PC records the voltage reading of the transmitter output.

ON-OFF Moisture Control:

The soil moisture content block diagram of an ON-OFF controller between the irrigation pump and the soil is established. The irrigation pump, which is driven by the Solid State Relay. The loop control system structure is shown in Fig (6).

As ON-OFF controller is used, having a dead band, the parameters of this controller are the minimum value 11.04% (as 1.6 from Wp) and the maximum value 28.4% (as the F.C.) of moisture content. From the obtained soil analysis, the irrigation is activated when the moisture content becomes less or equal to 11.04%. It is inactive when the moisture becomes greater than or equal to 28.4%.

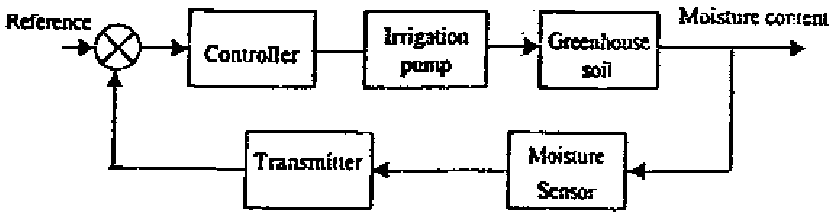

Fig. (6): ON-OFF soil moisture content control block diagram.

RESULTS AND DISCUSSION

1- The Sensor Calibration.

1-1-Calibration of the ELE sensors

Fig. (7-a) illustrates the relationship between the soil moisture content and the response resistance values of (ELE) sensor. It is interesting to note from Fig.(7-a) that when the values of electric resistance of "ELE" sensors decreases the soil moisture content increases. This relation tend to take the e^x relation and the general equation may take the following shape

$$\Omega_m = 892.847\ e^{-0.2565\ T} \qquad R^2 = 0.958$$

The differences between the level "ab" and "a1b1" are constructed in the curve in Fig. (7-a) to indicate the sensor-working period. This period depends on the differences between the field capacity and wilting point of soil. The "a_1d_1" level is considered as a start of irrigation (above wilting point) while the "ad" level is considered as the end of the irrigation period (field capacity).

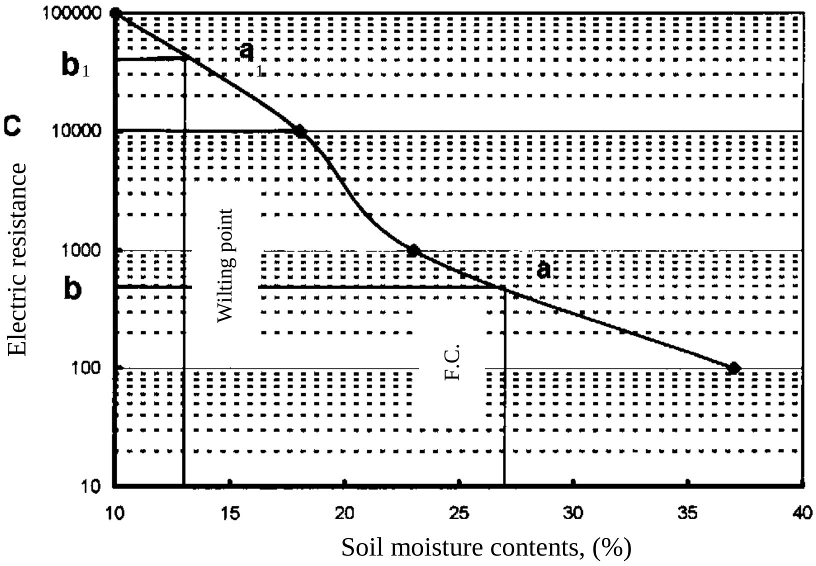

Fig. 7-a: Calibration of the ELE sensors.

1-2-Calibration of the two-electrode sensor

Fig- (7-b) indicates the relationship between the soil moisture content and the response values of volts for the two-electrode. The transmuted circuit was adjusted to record the 11.0% soil moisture content as a start of irrigation and the maximum soil moisture (28.4%) as the values number of "5" to end irrigation.

Generally, increasing the soil moisture content increases the conductivity sensor. This relation tends to take the logarithmic curve and the general equation may take the following shape:

$\Omega_m = 2.9257 \, Ln \, (T)^{-40689}$ $R^2 = 0.9895$

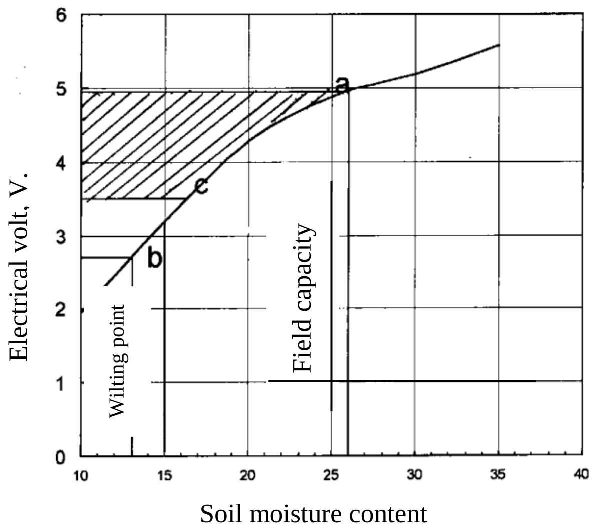

Fig. 7-B: Calibration of the two-electrode sensors.

The relation between the soil moisture content and the transmitter voltage was obtained as shown in Fig (8). The obtained results show that the two-electrode sensor could be used as a feedback element due to the following feature:

1-In the two-electrode sensor, the voltage increases as moisture increases, but this is not well defined in the ELE sensor.

2-The two-electrode sensor is a single value function, while the ELE sensor is a multi one, so it is impossible to obtain one output voltage of the sensor, for one moisture content value.

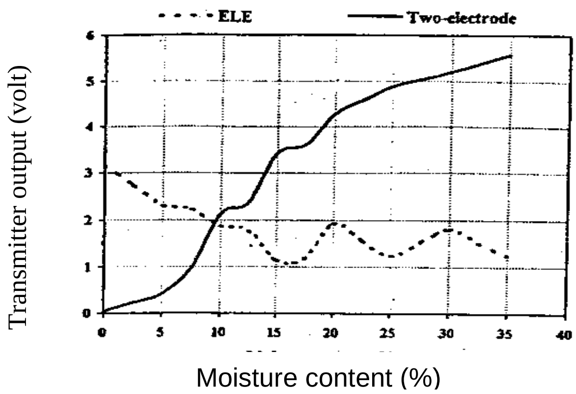

Fig. (8): Soil moisture content via transmitter voltage.

2- Soil Moisture Content Response.

It is very important to study the dynamic behavior of the soil moisture content (using the two sensors just mentioned), namely delay time overshoot, settling time and rise time. The study of these dynamic characteristics gives an important insight about irrigation and sensor response, to perform suitable plant irrigation. It's desired to affect the system of soil by a suitable increase or decrease in step function (water). This can be established by abrupt changes in the soil moisture from 11% to 28.4% and from 28.4% to 11% as shown in Fig. (9).

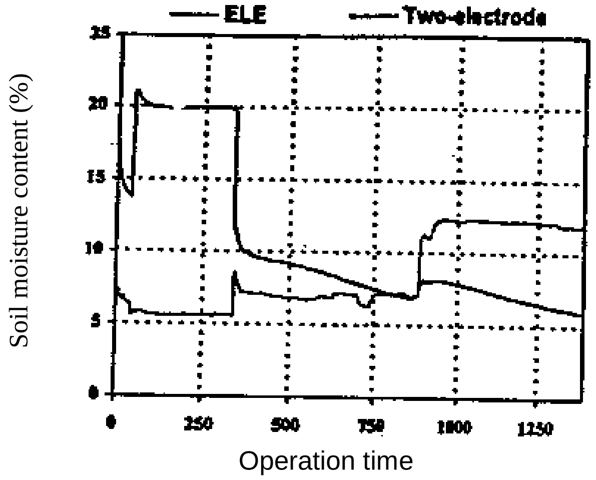

Fig (9) shows that the set up response of the soil moisture content, using the two-electrode sensor, is well defined (denoted by the up arrow). The response is fast, and there is a remarkable overshoot of 40%. On the other hand when a step down function is applied to the soil (denoted by the down arrow), the response is also very fast using the two-electrode, with a remarkable linear variation with time. In the case of using the ELE sensor, the soil moisture response is not well defined and there is a very large delay in time.

3-ON-OFF Moisture Content Control

Fig. (10) shows the transient response of the soil moisture content. The controller parameters are chosen to be the minimum value of 15% and the maximum of 25%. This figure is divided into regions. Region 1, at which there is no irrigation. In this region the sampling period is chosen to be large (5 minuets), therefore the soil does not reach the wilting state within this sampling time. Region 11 where the irrigation takes place. In this region, the sampling period is chosen to be small (5 seconds), in order to protect plants from excessive irrigation.

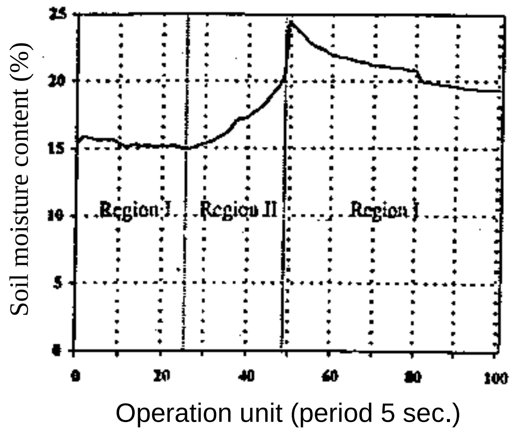

Fig. (10): Moisture response transient using ON-OFF controller.

Fig. (11) illustrated the relationship between the resting time of irrigation period and the values of response of transmitted circuit a two-electrode sensor. The transient circuit was adjusted to reduce the lowest value of soil moisture content (wilting point- 6.5%) as 2.6 volt. While the highest value (field capacity- 35%) of it was adjusted as 5 volt.

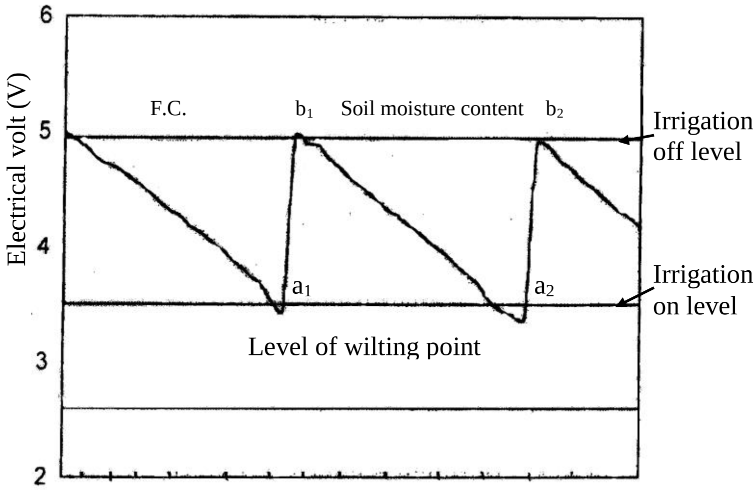

Fig. (11): The inclination of moisture response of two-electrode censor.

From the Fig. (11) the level "A" is considered as the wilting point, while level "B" is 60% of the wilting point. This point is considered as the level of ON irrigation. Level “C” represents the filed capacity (OFF of irrigation). After irrigation the level of soil moisture content decreases, this behavior is represented as “b_1a_2” line (Fig.-11). At point a_2 the two-electrode sensor sent the signal to open the irrigation net through the transmitted circuit. The delayed time of this signal depends on the quality of sensor. From the above figure it is easy to see that the lowest inclination of signal response was found at open irrigation circle (ON) and vice versa at closed (OFF).

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التحكم فى محتوى رطوبة التربة كهربائياً

زكريا إبراهيم إسماعيل
قسم الهندسة الزراعية - كلية الزراعة - جامعة المنصورة

تناول البحث إمكانية استخدام الدوائر الكهربائية للتحكم فى إمداد التربة بالماء المتاح لرى المحاصيل المنزرعة لنظام كامل التحكم لبيت محمى (Green house) عن طريق مجسات مختلفة لقياس الرطوبة. استخدم الباحث لتحقيق التجربة ثلاث أنواع من المجسات المتصلة بدوائر تحويل الإشارة (SSR) إلى صمامات رى كهربائية وبالتالي يمكن عن طريق إرسال تلك الإشارات إلى الصمامات أن تعمل على غلق دائرة الري أو فتح دائرة الري نظام (On-Off) فالإشارة المرجعية (Feed back) والقادمة من المجسات تتوقف على طبيعة التربة. وجد أن التربة ذات الأملاح العالية تؤثر على مقدار الإشارة وبالتالي يحدث انحراف فى مستوى ري المحصول. أدت المفاضلة بين المجس ELE والمجس المصنوع من الجبس والمجس المزود بقضيبين للجس إلى تباين الإشارة المرجعية لكل نوع. وكان المجس المزود بقضيبين للحس هو أقلهما تأثراً بالأملاح المنتشرة فى التربة. لذلك يفضل استخدامه في الأراضي العالية الملوحة.