DEVELOPMENT OF AN AUTO-IRRIGATION SYSTEM

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ABSTRACT

Water is an essential input for agriculture. With the increasing demand of this resource it has become essential to economize on water, particularly in activities related to agriculture. Scientific irrigation scheduling with automatic control of water application at pre-decided soil water tension is one way to effectively economise the use of water for irrigation. To achieve this an auto-irrigation system has been developed. In this system soil water tension is sensed with a modified manometer type tensiometer.

At the pre-decided soil water tension an electrical signal is generated which operates a valve (in case a tank is provided) or motor. A circuit has been designed and fabricated to control the operation of the valves or the motors with respect to these electrical signals. Alternately the design provides for control of irrigation with a pre-programmed timer. The developed circuitry has very low power requirements and can be operated with a 12 volt DC storage battery for a long period of time thus avoiding frequent recharging.

1. INTRODUCTION

Water is an essential input for agriculture. With increase in agricultural activity and competitive demand from other sectors, it is essential to use water more efficiently. Scientific irrigation scheduling is one way by which water could be saved in agriculture. Most of the times irrigation scheduling is done on the basis of soil water tension. If the start and close of irrigation is automatic (at two pre-decided values of soil water tension) it would not only save water but would also reduce labour requirements as well. To this end a device which controls irrigation time automatically at per pre-determined values of soil water tension has been developed. Design of the set also provides for automatic pre-programmed time controlled irrigation in place of a tensiometer controlled irrigation. The device helps in avoiding deep percolation losses due to over irrigation and crop losses due to over/under irrigation. The objective of the present paper is to present details of the design of value, control circuitry and preliminary test results. The cost of the set is also calculated for the benefit of the reader.

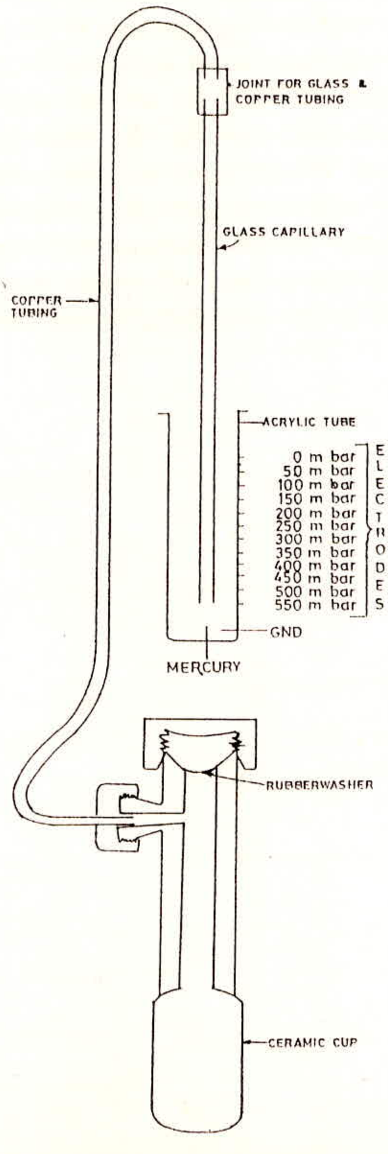

Fig 1. Modified Mercury Tensiometer.

2. MATERIAL AND METHODS

Tensiometers are being used increasingly for assessing soil water conditions at different depths of soil. The design of the manometer type tensiometer has been modified as shown in Fig. 1. The mercury cup has been replaced by an acrylic tube of internal diameter (1 cm) close to the outer diameter of the capillary glass tube. A helical groove has been cut on the upper surface of the acrylic tube and copper/steel electrodes have been installed equidistantly along the helical groove, the lower most electrode has been earthed (+12 volts). At zero soil water tension is (0) the mercury is at the top most position in the acrylic tube and earth is extended to the first (top) electrode through the mercury. As the soil water tension increases, the mercury in the acrylic tube goes down and earth gets progressively disconnected from different electrodes. These electrodes need to be calibrated with respect to a standard tensiometer installed under similar conditions (The electrodes are connected to the switching circuit through SPST switches).

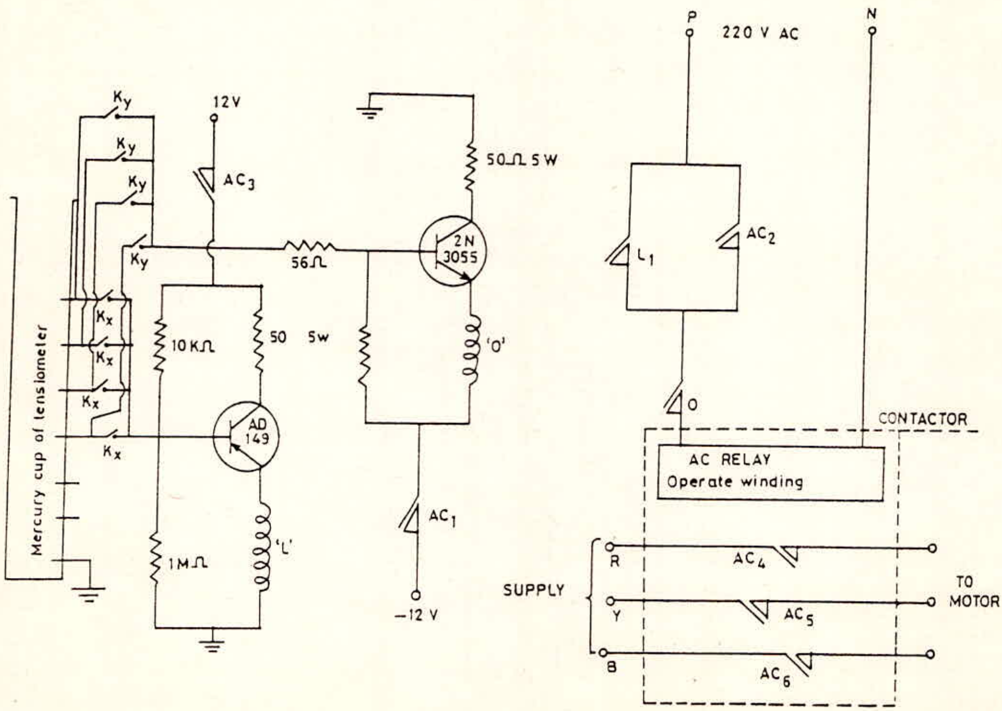

Fig. 2 Automatic Irrigation System

Depending on the value of the soil water tension at which irrigation is to be initiated or terminated, corresponding switches are closed. With the rise of soil water tension, the earth gets progressively disconnected from various electrodes but the sensor circuit is connected to the switch $K_x$which is closed. With the removal of earth a switching circuit using semiconductors and 12 volt dc relays (Fig. 2), switches 'ON' the motor or opens the valve at an appropriate instant.

With the onset of irrigation soil water tension starts falling and there is corresponding rise in the level of mercury in the acrylic tube. As the soil water tension falls to a predetermined value, the mercury also touches a corresponding electrode. Thus earth again gets extended to the switching circuit through switch K_y, which has already been kept in the close condition while other switches are open. Switching circuit gauges this earth condition and the three phase supply to the three phase irrigation motor is disconnected. Thus irrigation is terminated automatically till such time when the soil water tension rises again to a value at which irrigation is to be initiated by closing a particular switch that pertains to the soil water tension at which irrigation is to be initiated. The circuit has been designed for complete automatic operation. There is a minimum of load on the electronic components and dc supply source, thus ensuring longer trouble free working life.

3. WORKING: TENSIOMETER CONTROLLED IRRIGATION

The tensiometer is installed in the field at a representative location both with respect to space and depth. After properly charging and setting the tensiometer for two values of soil water tension one at which irrigation is to be initiated and the second at which irrigation is to be terminated. The corresponding switches K_x and K_y are closed (Fig. 1). 12 volt battery connecting switch is also switched 'ON.'

Due to evapotranspiration and evaporation, soil water tension rises resulting in a corresponding fall in the level of mercury in the acrylic tube. As the mercury level goes down, the earth gets progressively disconnected from the electrodes. When the earth gets disconnected from the electrode corresponding to switch K_x, the earth at the base of T_{x-1} transistor get disconnected and the negative potential is available at the base through voltage divider circuit $R_1 - R_2$ Since the base emitter junction of T_{x-1} being a PNP transistor becomes forward bias the T_{x-1} conducts. Thus current flows through coil (Fig.2) of relay (L) and the relay 'L' operates and contact L_1 closes. As shown in Fig.2 one of the phases is connected to coil of AC contact or relay, through contact L_1. As the contact L_1 closes, AC is extended to operate winding of contractor relay which operates and three phase supply is extended to the three phase induction motor. With the operation of AC relay contact AC_3 opens up and the –12 volt supply to the T_{x-1} is disconnected, supply to AC relay is held through its own operated contact AC_2 as shown in Fig. 2.

With the onset of irrigation the soil water tension value goes down, the level of mercury in the acrylic tube starts rising and the earth gets progressively extended to various electrodes. As the mercury rises to the electrode corresponding to closed switch K_y the emitter base junction of T_{x-2} (NPN transistor) gets forward biased 'O' relay operates contact O, opens, the AC supply to contractor thus gets disconnected, AC relay releases, contacts AC_4, AC_5, AC_6 open, the three phases supply to the induction motor gets disconnected and irrigation stops. In this way, the irrigation is controlled automatically between two predetermined values of soil water tension.

3.1 Time Controlled Irrigation

Alternatively the duration of irrigation can also be controlled with a programmable timer connected as shown in Fig.2. When the preprogrammed time has elapsed, the timer disconnects supply to AC relay of the contractor. The time is continuously monitored, thus the total amount of water applied can also be calculated. After completion of one irrigation cycle, the timer is again programmed for the next irrigation cycle. The three phase inductor motor can get damaged due to imbalance in the three phase supply, and this is taken care of by incorporating an unbalanced detection circuit. In case of a phase failure or low phase or wrong connnections the imbalance detecting relay operates and three phase supply to the motor is disconnected.

3.2 Irrigation with Automatic Valve

While the above method is suitable for a single plot where surface irrigation is applied, for different plots connected with a common supply system individual control is needed. In a drip irrigation set up also there is need to irrigate different literals at different values of soil water tension or for different durations. To meet this requirement an electrically controlled valve which can be operated automatically with respect to predetermined values of soil water tension or with respect to preprogrammed time has been developed. An electrically controlled valve can be operated with 12v dc. The circuit has been designed to limit the requirement of current to the instants of opening and closing valve, thus minimizing the drain on the battery.

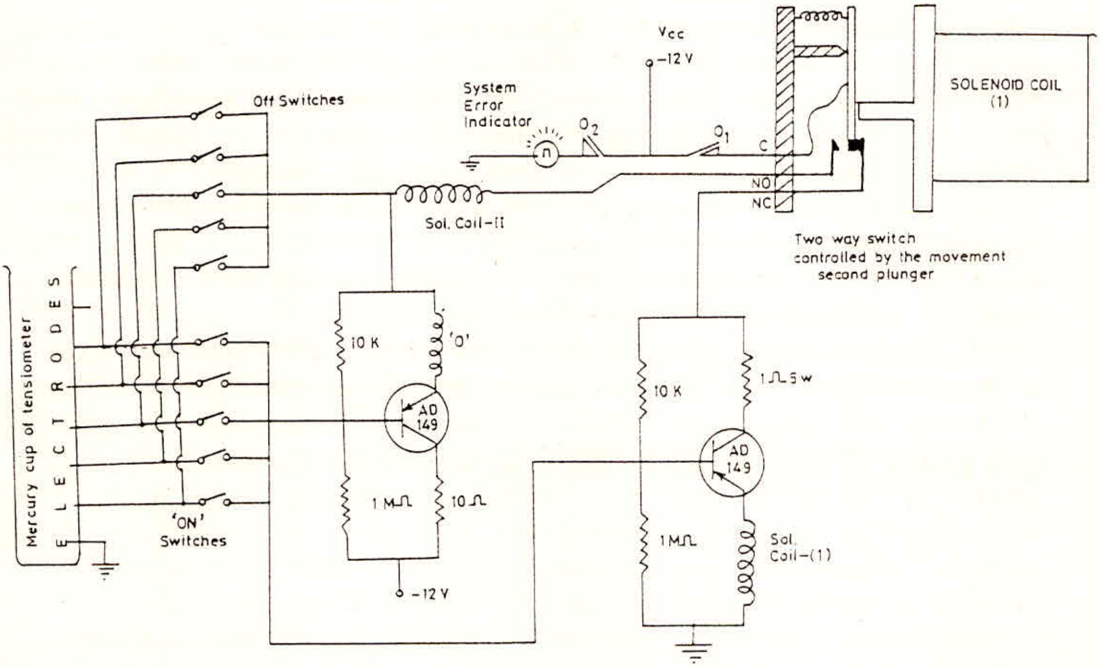

Fig.3 Circuit Diagram of Automatic Irrigation Valve

A single storage battery can be employed for operations of many laterals individually in field conditions without the requirements of frequent charging of the battery. The battery can be charged with a solar panel. The output of the solar panel and battery is kept in float condition. This arrangement can supply the required power reliably over a long period.

3.3 Working and construction of electrically controlled valve

As indicated in Fig.3 the valve has the following main parts:

- Aluminium base
- Plunger
- Solenoid coils
- Electronic sensing and control circuit.

An aluminium base circular in shape having external dia 6 cm is connected to the irrigation supply line through inlet (Fig. 3) nipple A the inlet channel opens near a rubber seal 'S'. The seal 'S' is shaped to have close contact with the seat made on the inner side of the aluminium base, the upper side of the rubber seal is hardened and has a cavity for elastic fitting of one end of plunger 1. Plunger 1 is made up of soft iron and is of 6.3cm in length. The seal 'S' is held in position along the periphery of the aluminium seat by rubber fixer 'F' which rests on the seal 'S' and fits with the circular walls at the inner side of the aluminium base. The rubber seal is held in position along the periphery by the rubber fixer and PVC disc of 7 mm thickness which has an elevated portion at the bottom which fits into the cavity of the aluminium base. The elevated portion presses the fixer and thus the rubber seal against the seat of the aluminium base, while the upper side of the PVC disc holds the PVC tube of dia. 5 cm. The central portion of the rubber seal 'S' is connected with the lower thick part of plunger (1) and can move with the movement of plunger (1). The plunger presses the control portion of the rubber seal against the inlet by a spring tension provided by spring 'T' which is housed on the seat grooved on the upper portion of the plunger (Fig. 4) and bronze cylinder, the top of plunger has a hole threaded into it, in which a bronze rod is threaded, so that spring 'T' is pressed between the seat on the plunger and bottom of the bronze rod, which ultimately comes out of the iron cover provided at the top and PVC tube rests on the inner portion of the iron cover.

The plunger is held so that the aluminium base, plunger, bronze cylinder, PVC tube are all concentric. A coil is placed around the bronze cylinder and inside the PVC tube. The coil is made of copper of size 26 SWG. The coil has 500 turns and generates sufficient flux to lift the plunger against the spring tension of spring T_1. Normally the inlet is held in the closed position by the rubber seal with the help of a spring tension provided by spring 'T'. The soil water tension is continuously recorded by the tensiometer installed at a suitable depth. When the soil water tension reaches a predecided value Fig. (5), the mercury in the acrylic tube of the tensiometer goes down and when the mercury drops below the level of the electrode associated with the switch at which irrigation is to be initiated, then the earth from the base gets removed. The base emitter junction becomes forward biased and switches 'ON'. The current flowing through the coil of solenoids I generates a magnetic field, thus plunger *P* is attracted towards the iron cover at the top of the PVC tube. The central portion of the rubber seal also moves up with the plunger because of snug fitting of the inlet and the valve opens and water starts coming out of the outlet nipple. As the plunger moves up, the bronze rod at the top of the plunger, also moves up. This bronze rod has a groove cut on its top. As the plunger moves up this groove is exposed to the tip of another iron plunger which continuously presses against the bronze head of the first plunger on account of the spring tension provided by a spring housed on the back of plunger P_{II}. The plunger now mechanically engages the bronze rod on top of P_I. A solenoid coil *II*, bronze cylinder, PVC tube, surround plunger P_{II} as in the case of plunger I. When the soil water tension drops to a pre-determined value at which irrigation is to be terminated, the earth is again extended to the electrode corresponding to switch K_y. The circuit for the solenoid coil *II* thus gets closed, (Fig. 5) solenoid coil *II* operates, plunger P_{II} moves back against spring tension, the plunger *I* thus gets unhooked and moves back to its original position under the effect of the spring tension of spring T_I. Thus the central portion of seal 'S' which is engaged with the plunger *I* also moves down and closes inlet of the water in the aluminium base, thus terminating irrigation for a particular lateral for which the soil water tension valve has reached a predetermined value for termination of irrigation.

Similarly water supply to the various laterals is controlled individually depending upon predetermined values of soil water tension sensed by the tensiometer installed along each lateral. As the plunger *II* engages plunger *I* mechanically, immediately after the operation of plunger *I* and the dc supply is disconnected, there is negligible load on the battery. At the time of termination of irrigation, solenoid coil II is energised only for a few seconds thus again there is very little load on the battery.

In inoperative conditions the plunger *I* presses against the contacts (C–1). –12 volts is available for operation of T_{x-1}, when the solenoid coil *I* is energised, plunger *I* moves and is engaged mechanically by plunger *II*, C contacts also changes over and –12 volts supply to the T_{x-1} is disconnected.

When solenoid *II* is energised plunger *II* disengages plunger *I*, plunger *I* is released and again presses contacts, which change over. Thus –12 volts is again available for the next operation of T_{x-1} and initiation of irrigation when the earth again gets disconnected from the closed switch pertaining to predecided value of soil water tension for initiation of irrigation.

3.4 Working of error indication circuit

If the appropriate switches are pressed then there is no possibility of having no earth condition at base of T_{x-1} and earth at emitter of T_{x-3} or earth at emitter of T_{x-1} and no earth at base. If the appropriate switches are not operated then the no earth condition at base and earth at emitter of T_{x-1} make the PN junction forward bias, the T_{x-1} conducts relay 'O' operates and lamp P lights indicating error in operation or switch or an error in circuit, the lamp goes off when the error is rectified.

Precautions

1. The soil water tension selection switches K_x and K_y should be set prior to switching 'ON' the –12 volts supply.
2. 12 volts battery should be charged at suitable intervals and electrolyte should be topped up, as and when required.
3. The valve should not be used against heads of more than three metres.

4. RESULTS AND DISCUSSION

The developed device has been tested successfully for controlling irrigation automatically as per predetermined values of soil water tension sensed by tensiometers installed at suitable points in the field. The automatic system can be applied for surface irrigation, drip irrigation or sprinkler irrigation.

In drip irrigation individual laterals can be controlled independently by opening and closing of associated valves as per predetermined values of soil water tension automatically. Electrical energy is utilized only for energisation of valves at the time of initiation and termination of irrigation. Since only 12v dc battery is used there is no risk of current leakage and shock to personal using the equipment.

The desired valve can be effectively used up to a water head of three meters. For larger heads the spring tension becomes excessive and solenoids have to generate a stronger magnetic field, therefore the design becomes difficult. To meet irrigation requirements with water head more than three meters, valves with different designs are required to be used. The cost of a single unit excluding the cost of tensiometer has been calculated at Rs. 1000/- only.

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