DESIGN OF A SEQUENTIAL IRRIGATION SYSTEM FOR ON FARM WATER MANAGEMENT

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ABSTRACT

To obtain maximum crop yield out of the inputs like water, fertilizer, food, seed etc., invested in crop production, the most important single factor is the field water management. Crops should be irrigated at the proper soil wetness with just enough water to replenish the soil moisture deficit created in the root zone. Therefore a well-controlled irrigation system is one, which optimizes the spatial and temporal distribution of water, not necessarily to obtain the highest yield or to use the least amount of water possible, but to maximize the benefit-to-cost ratio. Tensiometer and gypsum block are the two basic devices that can be used as soil moisture sensors to schedule irrigation. Use of infiltrating agents and observation of moisture deficiency symptom are other methods for irrigation management.

In order to control irrigation automatically by continuously monitoring soil water requirement, an electronic tensiometer and an electrical resistance sensor were developed at Central Plantation Crops Research Institute, Kasargod and are being used. But sensitivity of a tensiometer is upto a maximum of 0.85 atmospheres beyond which it seize to function. Many times the soil moisture tension is to be measured even up to 15 atmospheres. However electrical resistance sensors are used for measurement of soil moisture *up to this range.* Another method of scheduling irrigation is by sequential irrigation system. This paper gives the sequential irrigation system developed at Central Plantation Crops Research Institute. It consists of a time switch and a switching circuit. According to a set time in the time switch, a control circuit operates a solenoid valve connected on the irrigation pipeline to switch on the irrigation and keep it on for a predetermined period of time and then switch it off.

The heart of the time switch is a quartz oscillator vibrating at a particular frequency. This frequency is converted to a 1 Hz. pulse in an integrated circuit. This pulse drives a stepper motor, which in turn drives a gear train that is connected to a switching dial. According to a set time in the time switch, a control circuit operates the solenoid valve or the starter of the electric pump either to switch on or switch off the irrigation. This system was installed in a coconut garden and was tested for one season. It is reported that the irrigation requirement for coconut palm is 32 liters/palm/day. Accordingly the number of hours the irrigation is to be done can be calculated by knowing the operating pressure in the irrigation pipeline and discharge rate of the emitter used.

Depending on the availability of electric supply the starting time, the period, and the end point of irrigation can be set in the time switch. The practical utility of this circuit is that, this can be used along with any high frequency irrigation system such as sprinkler, perfo etc. and this works automatically and so no man power is required to do the irrigation.

INTRODUCTION

Irrigation is the process of applying water essential for crop growth (Israelson, 1967). To obtain maximum crop yield out of the inputs like water, fertilizer, food, seed etc., invested in crop production, the most important single factor is the field water management. Crops should be irrigated at the proper soil wetness with just enough water to replenish the soil moisture deficit created in the root zone. Therefore a well-controlled irrigation system is one, which optimizes the spatial and temporal distribution of water, not necessarily to obtain the highest yield or to use the least amount of water possible, but to maximize the benefit-to-cost ratio (Nakayama et al. 1986). Uniform irrigation methods such as center pivots, lateral move, mini-sprinkler, trikkler and subsurface maintain constant soil water level thus minimize or impose plant water stress at the desire of the irrigator (Phene et al, 1982). Irrigations based on soil water potential are the oldest techniques used. Tensiometers (Richards, 1936), thermal methods (Shaw, 1939), gypsum blocks (Boyoucos, 1940) and thermocouple psychrometers were all applied successfully. In order to have automatic control of irrigation by continuously monitoring soil water requirement, an electronic tensiometer and an electrical resistance sensor were developed at Central Plantation Crops Research Institute, Kasargod and are being used. (Madhavan et al 1998, CPCRI Annual Report, 1999). But sensitivity of a tensiometer is upto 0.85 atmospheres while the available soil moisture range is up to 15 atmospheres. However electrical resistance sensors are used for measurement of soil moisture *upto this range*. Another method of scheduling irrigation developed at Central Plantation Crops Research Institute, Kasargod is sequential irrigation system.

MATERIALS AND METHODS

Sequential irrigation system is an open loop control system in which the results of the operation are independent of the input and an operator is needed to make decisions; when to irrigate and how much to irrigate. It consists of a time switch and a switching circuit. According to a set time in the time switch, a control circuit operates a solenoid valve connected on the irrigation pipeline to switch on the irrigation and keep it on for a predetermined period of time and then switch it off.

The heart of the time switch is a quartz oscillator vibrating a particular frequency. This frequency is converted to a 1 Hz. pulse in an integrated circuit. This pulse drives a stepper motor, which in turn drives a gear train that is connected to a switching dial. According to a set time in the time switch, a control circuit operates the solenoid valve or the starter of the electric pump either to switch on or switch off the irrigation. This system was installed in a coconut garden having 36 palms. The plot was divided into two halves of 18 palms each. Water for irrigation was drawn from an overhead tank of 15-meter height. It was conveyed to the plot through underground PVC pipes. One number of two inch diameter electromagnetic valve (solenoid valve) was connected at the head end of each plot. The valve is normally closed and when it receives 220V electric supply, through the time switch it opens. Output of the valve was connected to 50mm (ID) HDPE main pipe. Sixteen millimetre LLDPE laterals were connected to the HDPE pipe using start connectors. Two microjets each having a range of 1 meter and discharge radius of 180° were used per palm. These microjets are attached to the laterals very close to the trunk of the palm in the opposite directions thereby getting the full basin area wetted. In this case at 15 meter of water column pressure the microjects discharged at a rate of 32 liters per hour. Previous experiments conducted at CPCRI using electronic tensiometer showed that when the upper limit of tension was set at 0.1 atm. and lower limit at zero tension irrigation was given on alternate days. Each time the system was operated for 90 minutes and 90 liters of water was applied per palm (Madhavan et al, 1997). The sequential irrigation system was set to operate from 10 am to 10-40 am thereby giving 43 liters of water per palm per day using two microjets. The system was also operated using 24 Volt DC solenoid valves .

RESULTS AND DISCUSSION

Design and Development of Soil Moisture Sensors

Soil moisture sensors suitable for different soil types were developed. These give an audio/video output to the farmer at any preset soil moisture level. For example, if the instrument is set at 50 percent of available moisture as 'on time' and at field capacity as 'off time', the same will give the user an audio/video signal when the soil moisture status reaches 50 per cent of the available moisture (preset value) so that he can start irrigation. Similarly it will give another signal at field capacity so that the user can switch off irrigation.

Design of an electronic tensiometer

Tensiometer is the only instrument to measure soil moisture tension directly in the field. Tensiometer measures the condition rather than the quantity of soil water and their operation is largely independent of the type of soil. Basic principle of this electronic tensiometer is simple. As the soil dries out and draws water from tensiometer, a negative pressure develops insode the tensiometer, which will be converted into electric signal by a pressure transducer and electronic circuit attached to it. Since a tensiometer is designed to measure water tension over a narrow range at low tension (0-1 bar), it is very suitable for light textured soil.

The electronic tensiometer consists of the basic tensiometer with vaccum gauge and a switching circuit. Basic tensiometer consists of a ceramic cup fused to a PVC pipe and a vacuum gauge. Distilled water is filled up in the tensiometer without any air bubble. The Electronic circuit diagram of the switching circuit is shown. There are two electrodes T1 and T2 provided just above the dial of the vaccum gauge so that the needle can just touch the electrodes when reaching at the pressure point where the two electrodes are set. The needle acts as the third electrode T3. T1 is the upper tension electrode and T2 the lower tension electrode. 12 V power supply is given to energise the switching circuit. There is a slot provided on the acrylic top cover of the vaccum gauge through which T1 and T2 can be slid to fix the tension points.

When soil dries out and draws water from the tensiometer through the porous ceramic cup, negative pressure develops inside the tensiometer, which will be measured in the vaccum gauge. The pressure gauge needle moves up and touches the upper limit tension electrode through which 12V supply is given to the base of the emitter follower circuit. The circuit energises the 12V relay. 220V AC line is then extended through the relay contact to the solenoid valve connected on the irrigation pipeline. The valve opens and starts irrigation. Alternately the relay contact can also be connected to a 220V / 440V coil of the motor starter to switch on the water pump.

Once Irrigation starts, the soil moisture tension reduces, the needle starts moving down, but the switching circuit continue to remain energized through the second contact of the relay.

The irrigation will be continued till the vaccum gauge needle touches the lower limit tension electrode T2. Since T2 is connected to ground, the switching circuit gets inactivated, relay re-energises and solenoid valve closes or the water pump stops. The tensiometer cup is fixed at t depth in the most active root zone of the plant. This depth and the maximum and minimum tension points vary from soil to soil and from crop to crop.

This study was conducted in a coconut garden of sandy loam soil. The tensiometer cups were fixed at 50 cm depth and 50 cm away from the bole. T1 was fixed at 0.1 atm. and T2 at zero tension. This was connected to a drip irrigation system. The system was tested for three seasons and found working well.

The electronic tensiometer can be connected to any high frequency irrigation system such as sprinkler irrigation, drip irrigation, perfo-irrigation etc. As the tensiometer can hold the negative pressure upto 0.8 atm only, it is better used in sandy and loam soils.

Design of an Alternate Sensor with Gypsum Block (Electrical Resistance Sensor)

Since resistance blocks are designed to measure water depletion over a wider range of water tension (1-15 bars), the block would be suitable for heavy soils. Working principle of gypsum block sensor is the change of resistance of the block with moisture. The resistance which is inversely proportional to the surrounding soil moisture, is converted to electric signals to active an audio/video output.

It consists of a pair of electrodes fused inside a gypsum block, a pre amplifier and an electronic comparator circuit. When the soil moisture is reduced below the preset level the comparator energises the relay circuit, which in turn switch on the solenoid valve or the water pump as the case may be. In the same way the system is switched off when the moisture level moves up to the pre set level. Alternately the system can be switched off after a preset time.

Calibration of the Sensors Developed

The above sensors were calibrated for different soil types. For this, simultaneous soil moisture measurements were taken by these sensors and by gravimetric method at different soil moisture levels. Once calibrated, the instrument can be set at any moisture levels as per the user requirement.

Design and Development of an Auto Irrigation System

Automatic Sequential Systems :

A suitable sequential control system was designed to turn the pump/ solenoid valve on at any point of time, allow it to run for a predetermined period of time and then to shut it off. This consists of a time switch and a switching circuit. The heart of the time switch is a quartz oscillator vibrating a particular frequency. This frequency is converted to a 1hZ. pulse in an integrated circuit. This pulse drives a stepper motor, which in turn drives a gear train that is connected to a switching dial. According to a set time in the time switch, a control circuit operates the solenoid valve either to switch on or switch off the irrigation. This system was installed in the coconut garden in front of the Kalpaka Guest House and was tested for one season.

Non-Sequential operating systems

These are fully automatic systems operating independently both in time and in quantity using electronic tensiometer and electrical resistance sensor as explained above.

An auto-irrigation system was designed using the above-developed sensors. Signals from these sensors activate either a solenoid valve connected to an online irrigation pipe or an electric motor to switch on and switch off irrigation. Once the irrigation starts, the soil moisture level gradually increases and reaches a preset value, generally field capacity, the sensor will send another signal to switch off the solenoid valve or electric motor there by stopping irrigation.

Field Evaluation of the System

The auto irrigation system was installed in three different soil types, i.e., sandy soil, sandy loam soil and laterite soil and evaluated. Accuracy and consistency of the equipment was worked out. It was evaluated against the conventional irrigation system. The control system with electronic tensiometer as sensor and the sequential irrigation system were found consistent where as the control system with electrical resistance sensor was inconsistent because the gypsum bloc, which was used for resistance variation, was not adequately sensitive and was slow to moisture variation in the soil.

CONCLUSION

The sequential Irrigation system could be used in places where electricity is not available. In such cases water can be pumped to the overhead tank using diesel pumps and the sequential system and the solenoid valve could be operated with battery. Depending on the availability of electric supply the starting time, the period, and the end point of irrigation can be set in the time switch. The practical utility of this circuit is that this can be used along with any high frequency irrigation system such as sprinkler, perfo etc. and this works automatically and so no man power is required to do the irrigation.

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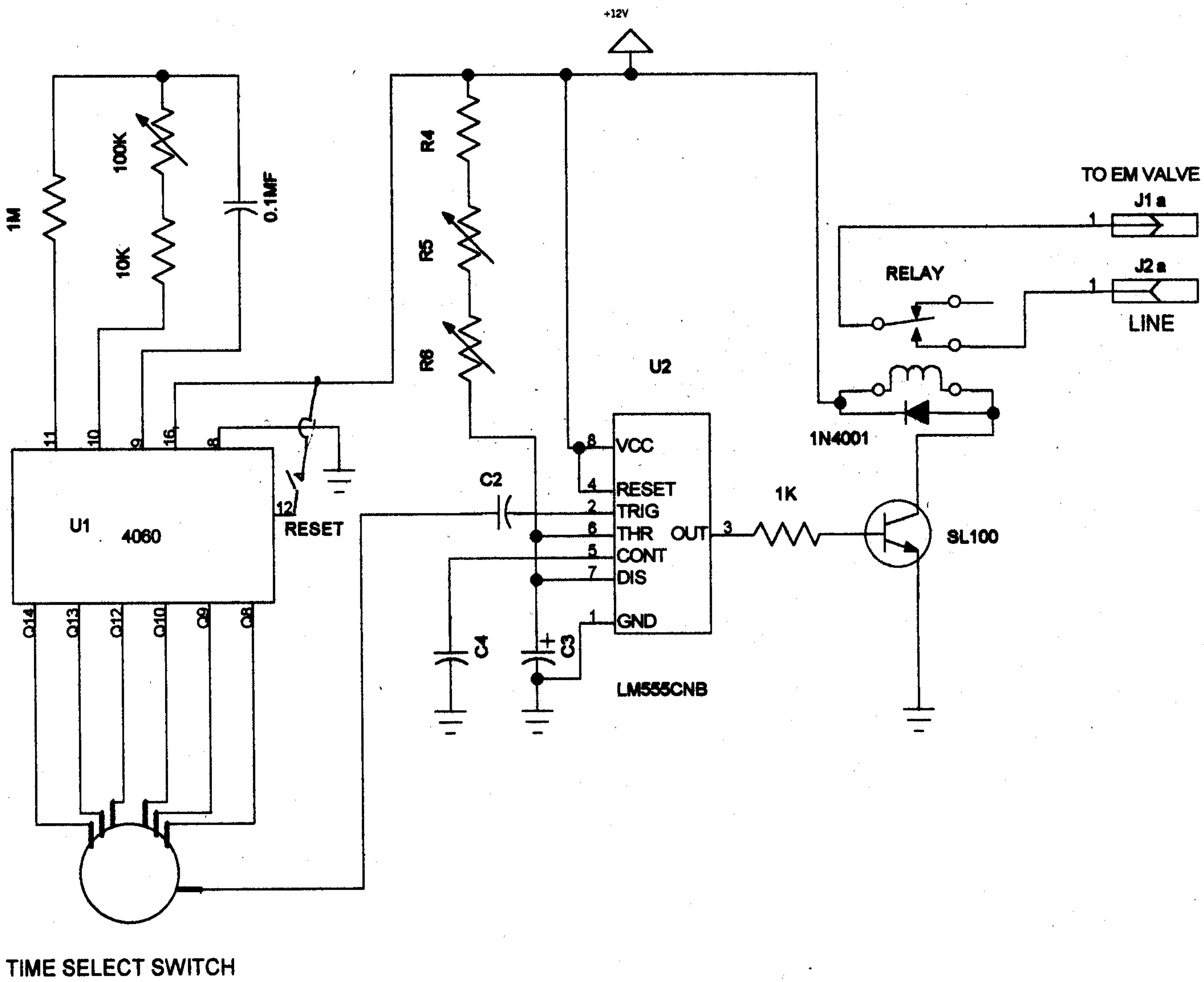

SEQUENTIAL TIMER CIRCUIT

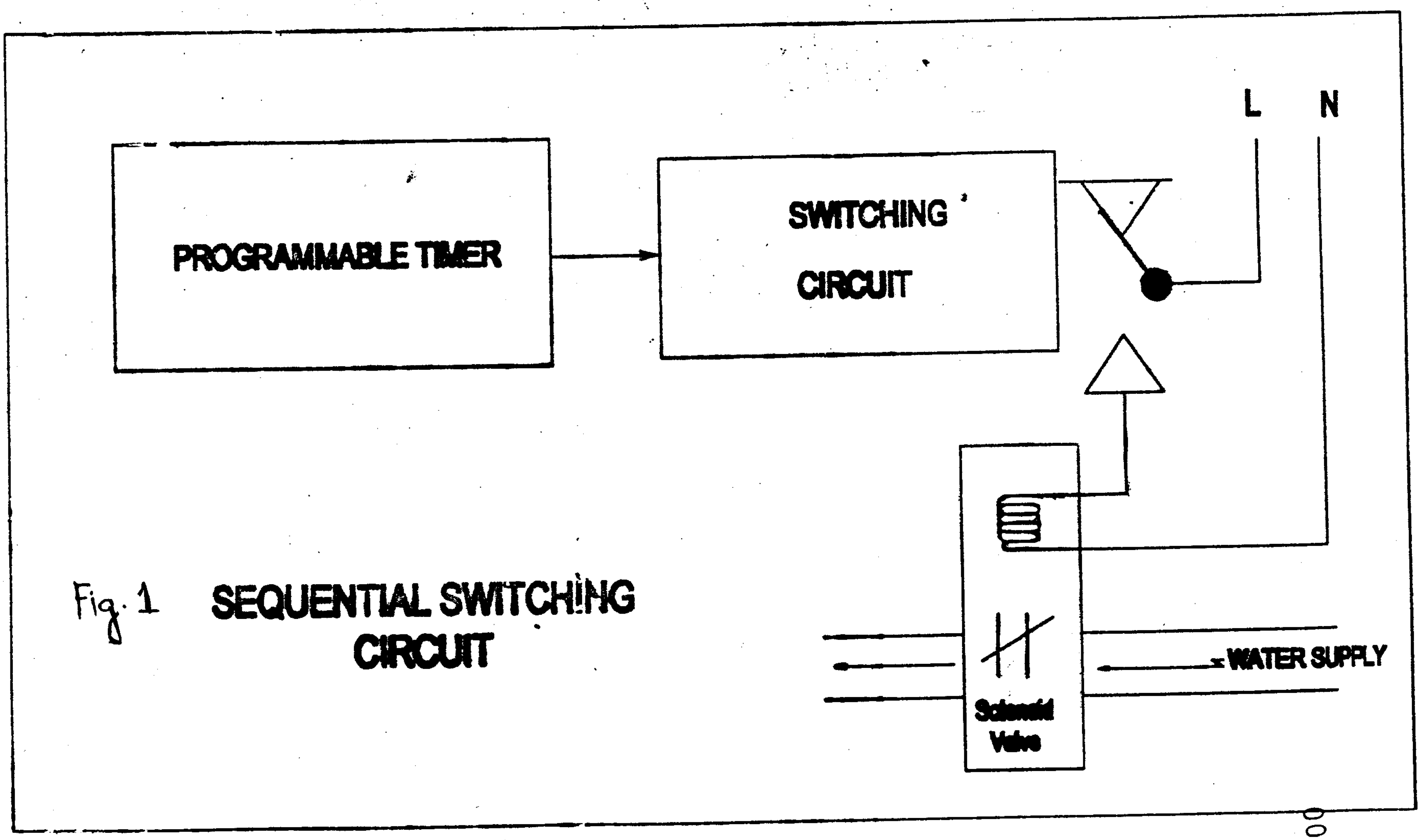

Fig. 1 SEQUENTIAL SWITCHING CIRCUIT