Sensor:

Sensor is a converter that measures a physical quantity and converts it into a signal which can be read by an observer or by an (today mostly electronic) instrument.

Sensor is a device, which responds to an input quantity by generating a functionally related output usually in the form of an electrical or optical signal. A sensor's sensitivity indicates how much the sensor's output changes when the measured quantity changes.

Soil moisture sensor as the name indicates is used to determine the moisture present in the soil. The moisture of the soil depends upon various factors such as type of soil whether its sandy, clay, loam, sandy loam and salts present in soil such as iron, manganese, calcium, phosphorus, nitrogen, sulphur etc. it also depends upon temperature. Based on the reading of moisture sensor, irrigation is done.

Soil Volumetric Water Contentbased soil moisture sensors:

These sensors are used to determine the amountof water present in the soil. VWC can be calculated by mass (g/g) or volume (cm3 / cm3). It gives output in percent content.

Soil Water Tensionbased soil moisture sensors:

These sensors measure energy of water in the soil. Water tension is measured in energy/mass of the soil. Units are Joules/kg (J/kg) or kilopascal (kPa). It tells how much difficult or easy it will be for the plant to extract water from the soil.

Types of sensors:

Water monitoring sensors can be divided into 2 types. They are Contact sensors, Non contact sensors.

Contact sensors:

Contact sensors are electromechanical devices that detect change through direct physical contact with the target object. Contact sensors,

- Typically do not require power;

- Can handle more current and better tolerate power line disturbances;
- Are generally easier to understand and diagnose.

Examples are Pressure sensor, Capacitance sensor, Resistance Sensor, Shaft Encoders, Bubbler

Non Contact sensors

Non-contact sensors are solid-state electronic devices that create an energy field or beam and react to a disturbance in that field. Some characteristics of non-contact sensors:

- No physical contact is required;
- No moving parts to jam, wear, or break (therefore less maintenance);
- Generally operate faster;
- Greater application flexibility.

Examples are Ultrasonic sensor, Radar sensor.

Automation:

Automation of drip/micro irrigation system refers to operation of the system with no or minimum manual interventions. Irrigation automation is well justified where a large area to be irrigated is divided into small segments called irrigation blocks and segments are irrigated in sequence to match the flow or water available from the water source.

Systems of Automation

Time based system

In time based system, time is the basis of irrigation. Time of operation is calculated according to volume of water required and the average flow rate of water. The duration of individual valves has to be fed in the controller along with system start time, also the controller clock is to be set with the current day and time. As the clock of the controller knocks the start time of programme, it starts sending signals to the first automatic valve in the programme sequence, the pump also starts up at the same time. As soon as duration of first valve is over the controller either stops or switches on to next valve. When the operation of last valve is over, controller stops sending signals to valves and pump. The same process is repeated at next run time.

Volume based system

In volume based system, the preset amount of water can be applied in the field segments by using automatic volume controlled metering valves. Automation using volume based systems are of 2 types. In first type of system, automatic metering valve with pulse output provides one pulse after completing one dial of the automatic metering valve. Thus, by counting the number of pulses received by the controller, it can count the volume of water passed through. After providing required volume of water through first valve, it closes down and controller switches on the next valve in the sequence. In second type of system, no controller is required. Automatic metering valves are positioned near each field segment. All automatic metering valves are interconnected in series with the help of control tube. For automatic closing and opening of the metering valves with the help of water pressure signal, components like t-connector, shuttle valve and a 3 way relay (called Shastomit) are also installed along the circuit. During sequential operation only one automatic metering valve remains open. The next valve in the series opens after the first valve closes. Shut down of the irrigation pump can be made automatic after closure of the last valve in series by connecting the spare end of the last valve T-connector to a microswitch with the help of control tube. Micro-switch is connected to the pump motor starter's magnetic coil. After the last automatic metering valve closes, it transmits pressure signal to the micro-switch with the help of pressure which in turn activates a pressure switch and terminates the motor starter circuit resulting in automatic shutdown of irrigation pump.

The major advantage of volume based irrigation system over time-based system is that assures to deliver the preset amount of water irrespective of continuous availability of electricity, but time based system is comparatively cheaper and hence gaining more popularity than the volume based system.

Open Loop Systems

In an open loop system, the operator makes the decision on the amount of water that will be applied and when the irrigation event will occur. This information is programmed into the controller and the water is applied according to the desired schedule. Open loop control systems use either the irrigation duration or a specified applied volume for control purposes. Open loop control systems are typically low in cost and readily available from a variety of vendors. The drawback of open loop systems is their inability to respond automatically to changing conditions in the environment. In addition, they may require frequent resetting to achieve high levels of irrigation efficiency.

Closed Loop Systems

This type of system requires feedback from one or more sensors. The operator develops a general control strategy. Once the general strategy is defined, the control system takes over and makes detailed decisions of when to apply water and how much water to apply. Irrigation decisions are made and actions are carried out based on data from sensors. In this type of system, the feedback and control of the system are done continuously. Closed loop controllers require data acquisition of environmental parameters (such as soil moisture, temperature, radiation, wind-speed, etc) as well as system parameters (pressure, flow, etc.).

Real Time Feedback System

Real time feedback is the application if irrigation based on actual dynamic demand of the plant itself, plant root zone effectively reflecting all environmental factors acting upon the plant. Operating within controlled parameters, the plant itself determines the degree of irrigation required. Various sensors viz., tensiometers, relative humidity sensors, rain sensors, temperature sensors etc control the irrigation scheduling. These sensors provide feedback to the controller to control its operation.

Computer-based Irrigation Control Systems

A computer-based control system consists of a combination of hardware and software that acts as a supervisor with the purpose of managing irrigation and other related practices such as fertigation and maintenance. Generally, the computer-based control systems used to manage micro irrigation systems can be divided into two categories:

- Interactive systems that collect and process information from various points in the system, and allow manual control of the system from a central point by remote operation of valves or other control devices.
- Fully automatic systems that control the performance of the system by automatically actuating pumps, valves, etc. in response to feedback received from the monitoring system. These systems use closed control loops which include:

- Monitoring the state variables (pressure, flow, etc.) within the system.
- Comparing the state variables with their desired or target state.
- Deciding what actions are necessary to change the state of the system.
- Carrying out the necessary actions. Performing these functions requires a combination of hardware and software that must be implemented for each specific application.

Interactive Systems

Interactive systems are usually built around a microcomputer, either a standard personal computer (PC) or a specially designed unit. The information is transferred into a central unit either directly from sensors in the pipeline or from intermediate units which collect the data from a number of sensors and then process and store them temporarily for further transfer to the central computer. These systems have features that enable the operator to transmit commands back to the various control units of the irrigation system. The field devices such as valves, regulators, pumps, etc. are fitted with electrically operated servo-devices which enable actuation of the pumps, closing and opening of valves, and adjusting pilot valves of flow regulators. This type of system permits the operator to govern the flow from the central computer by controlling flow parameters such as pressure and flow rate, according to specific needs at the given time, and to receive immediate feedback on the response of the system.

Existing Automated Drip Irrigation System

In Existing Automated Drip Irrigation system it is not possible to operate it on decisions, it just operated only on single soil conditions like soil moisture, ph value, temperature and light. It operates on only one condition at a time like if we using soil moisture sensor to control automated drip irrigation then whenever soil moisture level is get decrease then and then only it direct the valve to change its position from OFF to ON, and if soil moisture level is go to the proper pre-setted level at that time system is get OFF automatically.

Limitations of Existing System

In Existing Automated Drip Irrigation system it is not possible to operate it on Multiple decisions, it just operated only on single soil conditions like soil moisture, phvalue, temperature and light. It operates on only one condition at a time.

Review of Various Soil Moisture Measuring Techniques:

Need for Soil Moisture Measurements:

- Various physical & chemical properties of soil changes with amount of moisture present in soil.
- To measure changes in infiltration, irrigation.
- To study ground water recharge &Evapo-transpiration.
- It is also important in the fields like Hydrology and Forestry.
- To study & determine the parameters like soil profile, surface tension related with civil & soil engineering.

Gravimetric Technique

It is the most oldest, satisfactory & widely used soil moisture measurement technique. Used for calibration of other techniques.

Principle- Based on calculations of the weighing of the soil sample before & after the drying

Methodology- Measurement is carried out in following steps:

- Collecting soil sample- Using Sampling Augers, Sampling Tubes, Core Barrels or Open-drive Sampler.
- Weighing original soil sample
- Drying of soil- Oven drying or Radiation drying
- Weighing dried sample of soil
- Calculating amount of moisture content
- Percentage of moisture content = $\{(W_t - W_s) / W_S\} x 100$

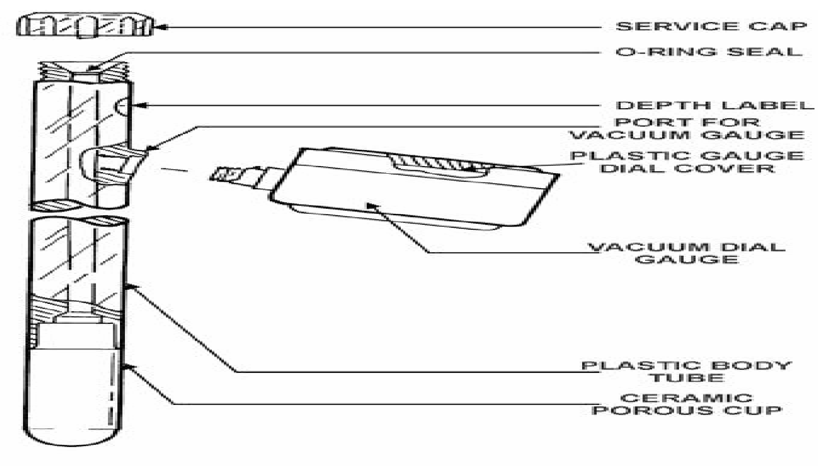
Tensiometer Method

Principle- Based on the property of the absorption i.e. Suction force of water for soil.

- Water comes into equilibrium with the soil solution through a permeable & saturated porous material if a sealed water-filled tube is placed with the soil.

Methodology-

- The permeable ceramic cup tip is placed with the soil in the root zone of plant.
- Water moves from the tube into the soil as the soil is normally not saturated, So that a partial vacuum (pressure) is made and evaluated by the gauge.
- Pressure varies with amount of water potential thus gauge indicate the moisture content in the soil.



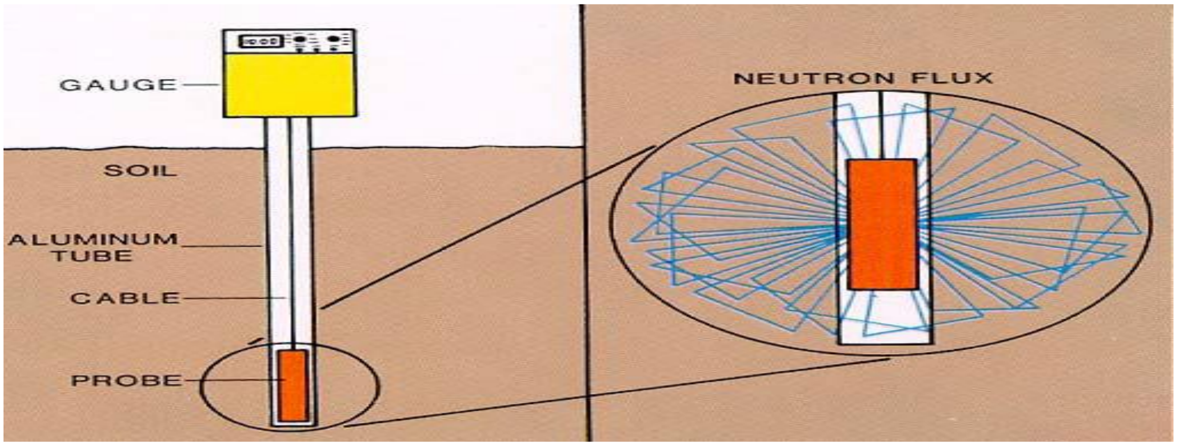
Neutron Scattering

Principle- High energy is lost in Neutron collision with atoms having low atomic weight like hydrogen atoms. Water content these atoms on very large scale.

Methodology-

- Uses a long & narrow cylindrical probe containing source & detector for neutrons.
- Probe is then inserted in soil & source is then activated
- The effect of collisions changes a fast neutron to a slow neutron.

- The number of slow neutrons detected by a counter tube electronically
- Measuring Gauge is calibrated in terms of moisture content

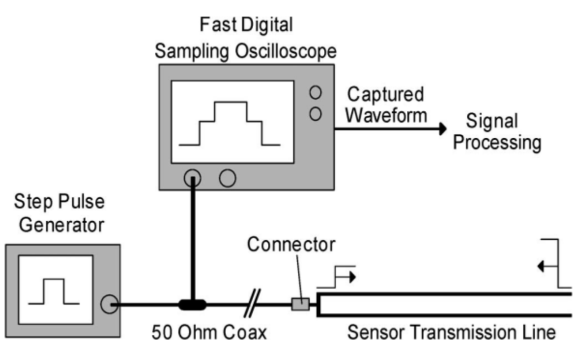


Time Domain Reflectometer (TDR)

Principle- Dielectric constant of soil is the function of content of moisture present in soil. Traveling time of a EM wave changes as velocity of traveling wave is affected by the dielectric constant of soil.

Methodology-

- An open ended sensor transmission waveguide is designed & inserted in soil.
- A pulse of EM is transmitted through it. A part of signal reflected back which then observed using Sampling Oscilloscope.
- Using Time delay between transmitted &reflected signal soil moisture measurement is carried out.



Frequency Domain Reflectometer (FDR)

Principle- The electrical capacitance of a capacitor that uses the soil as a dielectric depends on the soil water content. When connecting this capacitor (made of metal plates or rods imbedded in the soil) together with an oscillator to form an electronic circuit, changes in the circuit operating frequency detects changes in soil moisture.

Methodology-

- Probes are designed using two or more electrodes (i.e., plates, rods, or metal rings around a cylinder) inserted into the soil.
- An electrical field is given then the soil around the electrodes serves as the dielectric of the capacitor that completing the oscillating circuit.
- By varying the frequency soil moisture is then measured

Amplitude Domain Reflectometry (ADR)

Principle- When an EM wave traveling along a TL reaches a section, part of the energy reflected back due to impedance mismatch. This reflected wave interacts with the original incident wave producing a voltage standing wave. Impedance of soil depends on the content of moisture that changes wave amplitude along the length of the TL.

Methodology-

- Sinusoidal EM wave is generated & applied to a coaxial TL that extends into the soil through an array of parallel metal rods.
- Its outer cover forms an electrical shield across the central rod. Rod assembly acts as an additional section of the TL having impedance depending on the dielectric constant of the soil between the rods.
- Depending on the amplitude change in reflected signal moisture content is determined

Phase Transmission

Principle- In travelling sinusoidal wave phase is shifted relatively after traveling fixed distance with respect to initial phase at the origin.

This phase shift depends on i) Length of travel along the TL

ii) Frequency and

iii) Velocity of propagation.

As velocity of propagation is related to soil moisture content, so it can be determined by this phase shift at fixed frequency and length of travel.

Methodology-

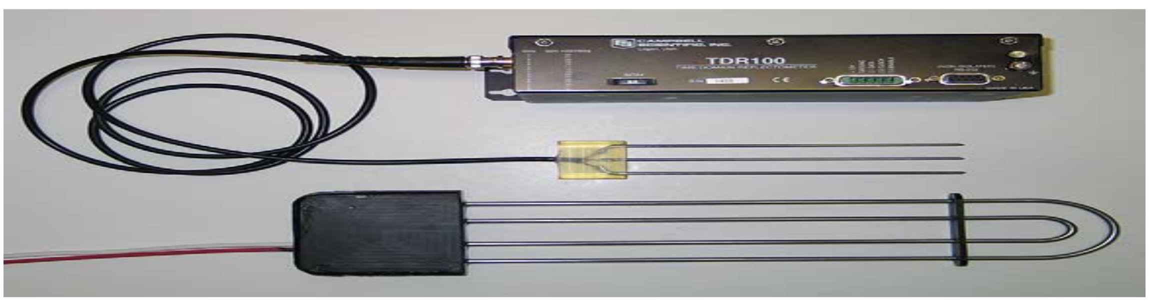
- Two open concentric metal rings are used to design a waveguide probe
- Phase is then measured at the beginning and ending of the waveguides.
- At the end soil moisture content can be devaluated easily depending on the phase shift

Time Domain Transmission (TDT)

Principle- Measurement of the propagation time over a known distance of the wave can be used to calculate the dielectric characteristics. To determine water content in a porous dielectric medium, an EM pulse is guided through the medium by a transmission line.

Methodology-

- It is similar to TDR, but requires an electrical connection at the beginning as well as ending of the TL.
- The probe has a waveguide design as bent rods of metals which are inserted into the electronic block on both side.
- Another way is the sensor consists of a long band (~3 ft), with an electronic block at both ends.
- Soil moisture is then easily calculated depending on the travel time of EM wave.



Resistive Soil Moisture Sensor:

It’s made of two exposed electrodes, and uses the fact that the more water the soil contains, the lower the resistance between the two electrodes. The resistance can be measured using a simple voltage dividier and an analog pin. While it’s very simple to construct, resistive sensors are not extremely reliable, because the exposed electrodes can degrade and get oxidized over time.

Capacitive Soil Moisture Sensor

Capacitive soil sensors are also made of two electrodes, but insulated (i.e. not exposed). The two electrodes, together with the soil as a dielectric material, form a capacitor. The higher the water content, the higher the capacitance. So by measuring the capacitance, we can infer the water content in soil. There are many ways to measure capacitance, for example, by using the capacitor's reactance to form a voltage divider, similar to the resistor counterpart. Another way is to create an RC oscillator where the frequency is determined by the capacitance. By counting the oscillation frequency, we can calculate the capacitance. You can also measure the capacitance by charging the capacitor and detecting the charge time. The faster it charges, the smaller the capacitance, and vice versa. The chirp which is an open-source capacitive soil sensor, works by sending a square wave to the RC filter, and detecting the peak voltage. The higher the capacitance, lower the peak voltage. Capacitive sensors are not too difficult to make, and are more reliable than resistive ones, so they are quite popular.

Advantage and Disadvantage of Soil Moisture Techniques:

Parameter	I GM	II NM	III TDR	IV FDR	V ADR	VI PT	VI TDT	(VIII) Tensi.
1) Requirement of Specific Calibration	N	N	Y	Y	Y	Y	Y	N
2) Affected by Soil Salinity & air gaps	N	Y	N/Y	Y	Y	Y	Y	N
3) Measurement at different depths	Y	Y	N	Y	N	N	N	N
4) Connection with Data Logger	N	N	Y	Y	Y	Y	Y	N
5) Time efficient	N	N	Y	Y	Y	Y	Y	N
6) Permanent Installation	N	Y	Y	Y	Y	Y	Y	N
7) Safety	Y	N	Y	Y	Y	Y	Y	Y
8) Automation	N	N	Y	Y	Y	Y	Y	N

Operating Range and Frequency:

Technique	Operating Range (ft^3 per ft^3)	Accuracy (ft^3 per ft^3)
Neutron Moderation	0 to 0.6	± 0.005
TDR	0.05 to saturation	± 0.01
FDR	0 to saturation	± 0.01
ADR	0 to saturation	± 0.01 to 0.05
PT	0.05 to 0.5	± 0.01
TDT	0 to 0.7	± 0.05
Tensiometer	0-0.80 bar	±0.01 bar

Measurement Volume and Cost:

Technique	Measurement volume	Cost (Rupees)
Neutron Moderation	Sphere(radius 6-16 inches)	6,00000-9,00000
TDR	About 1.2 inches radius around waveguide	2,40000- 1,380000
FDR	Sphere(radius 1.6 inches)	6,000- 2,10000
ADR	Cylinder (radius 1.2 inches)	30,000- 42000
PT	Cylinder	12,000- 24,000
TDT	Cylinder (radius 2 inches)	24,000-78,000
Tensiometer	Sphere (Greater than 4 inch radius)	4500- 15,000