Efficient Irrigation Using Closed-Loop Feedback

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The Intelligent Use of Water.™
“When the well’s dry, we know the worth of water.”

– Benjamin Franklin
97% of all water is saltwater, 2% is held in snow and icebergs. Only 1% is freshwater.
Historically, technology and lifestyle improvements have led to the doubling of water consumption every 20 years.
On average, residents in the U.S. use 101 gallons of water per day.
If water is used more efficiently, it can have a significant impact on the available supply.
The need to use water responsibly has never been greater.
Anatomy of Soil Water Content

- Saturation
- Field Capacity
- Control Range
- Plant Available Water (PAW)
- Permanent Wilt Point
- Management Allowable Depletion (50% of PAW)
- Parched

Gravitational Effects:
- Water Run-off
- Heavy Nutrient Loss
- Root Putrefaction

Wasted Water

Plant Stress

Plant Death

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Closed Loop Systems

- **Control Theory**
  - Scientific theory focused on influencing the behavior of dynamic systems

- **Open-Loop Control**
  - No direct link between the output of the system and the conditions being controlled

- **Closed-Loop Control**
  - A sensor is deployed to provide feedback
  - System output is controlled by the feedback signal
Open-Loop Control Systems

Reference → Controller → Dynamic System → System Output

Controller Program

Irrigation Water

Moisture at the Root Zone
Closed-Loop Control Systems

Reference → Measured Error → Controller → System Input → Dynamic System → System Output

Controller

Sensor

Measured Output

Volumetric Water Content

Moisture at the Root Zone
Application to Irrigation Systems

- **Traditional Open Loop:**
  - Root zone soil moisture is controlled without direct measurement/feedback
  - Plant moisture requirements may be measured by inference from related variables (weather)

- **Closed Loop Feedback:**
  - Root zone soil moisture is controlled by direct measurement and feedback
  - Precision is dictated by sensor
Closed-Loop Feedback System Advantages for Irrigation

- Measures moisture directly at the root zone
- No need for seasonal clock adjustments
- No need for any end-user intervention
- System automatically adjusts for varying temperatures, precipitation, and other changes in weather which influence soil moisture content
- Metrics are gathered directly from the site
- Water savings of 40% or more versus a well programmed standard controller
Smart Control with Soil Moisture Sensors

- IA SWAT recognition and testing
- Recognized by a growing list of water purveyors
  - Arizona
  - California
  - Colorado
  - Nevada
  - Oregon
  - Texas
  - Utah
  - Washington
Single Sensor Feedback Systems
Sensor Location

- Choose a full-sun location
- Avoid low spots where water typically collects
- Avoid high spots where drainage may not be representative of the site
- Avoid locations exposed to heavy foot traffic
- Avoid location near hard-scapes
- Avoid locations which are irrigated by more than one zone
Single Sensor Closed-Loop Feedback
Required Site Data

- Effective Precipitation Rate for Each Irrigated Zone
  - Used for tracking non-sensor zones to sensor zone
  - Program controller accordingly

- Nothing Else
Soil Volumetric Water Content (VWC)

- Water with ionic contaminants is a conductor
- Soil Constituent Permittivity Measurements:
  - Air: 1
  - Soil: 4
  - Water: 80
- Soil conductivity and permittivity can be used as a metrics to determine VWC
Soil Moisture Sensors
Historical Challenges

- **Accuracy**
  - The ability of a sensor to report absolute moisture values

- **Precision**
  - The degree of reproducibility of a sensor’s performance over time

- **Limited Sensor Life/Durability**

- **Difficult to install and Set-up**

- **Frequent Maintenance**
Sensor Types

- **Relative Soil Moisture Sensors**
  - Sensor reading changes with moisture content but also changes with other environmental conditions.
  - Relative sensors require calibration to the specific installation environment.
  - As the environment changes, the readings become unreliable.

- **Absolute Soil Moisture Sensors**
  - Sensor provides a stable moisture reading when soil type, compaction, electrical conductivity, or temperature changes.
Moisture Sensor Technologies

- **Soil Electrical Conductivity**
- **Soil Permittivity/Dielectric Constant**
  - Capacitance
  - LC Resonance
- **Electromagnetic Wave Propagation Time**
  - Various formats (TDR, FDR, TDT)
  - Analog
  - Digital
Measurement Methods

Electrical Conductivity (EC)

- **Basis:** Conductivity increases with water content (sometimes)

- **Advantage:** Low cost

- **Disadvantage:** Pure water is an Insulator and has no conductivity. Changes in ion concentration and temperature cause very large errors in this method.
Soil Moisture Measurement Methods

Permittivity Measurement - Capacitor

- Basis: Dielectric constant of water is ~30X that of other soil constituents.

- Advantage: low cost

- Disadvantages:
  - EC losses in the soil distort the capacitance readings
  - Dielectric constant of water is temperature dependent
  - Capacitive probes are ‘surface’ sensitive and thus subject to large air-gap errors
Soil Moisture Measurement Methods

Permittivity Measurement – LC Resonance

- **Basis:** Dielectric constant of water is ~30X that of other soil constituents.

- **Advantage:** Higher frequency operation results in EM wave penetration of the soil, reducing air gap problem.

- **Disadvantages:**
  - EC losses in the soil distort the capacitance readings
  - Dielectric constant of water is temperature dependent
  - Capacitive probes are ‘surface’ sensitive and thus subject to large air-gap errors.
Soil Moisture Measurement Methods

Time Domain Transmissometry + Digital Signal Processing

- Basis: Measures time for an electric pulse to travel along the sensor’s waveguide
- Patented technology
  - Digitizing the waveform at high frequencies
  - Signal processing required to extract the time delay information
- Advantages
  - Inherently stable readings of VWC
  - Measurements accurate with changing soil type, temperature, and EC

**Absolute Soil Moisture Measurements**
SMRT-Y Soil Moisture Sensor Overview

- Add-on device for all standard controllers
- Suspends irrigation when soil moisture exceeds a set threshold
- Bypass feature allows isolation of up to two zones from the influence of the sensor
- Simple installation and set-up
- Accurate and stable moisture readings – no calibration required
- Targeting residential and light commercial applications
- Makes any controller “Smart”
SMRT-Y Soil Moisture Sensor
How it works....Dry Conditions
SMRT-Y Soil Moisture Sensor
How it works….Wet Conditions
Simplified Sensor Installation

1) Select a full sun location for the sensor
2) Install the sensor 3 to 5 in. below the surface
3) Connect the sensor to the nearest valve
Sensor Wiring Detail

- Identify multiple sensor locations
- Choose a sensor location near a valve box
- Connect the sensor to an existing zone wire
User Interface Wiring Detail

- Connect the 24V and Common
- Identify the “Sensor Zone”
- Disconnect the zone wire and connect to Red
- Disconnect the field common and connect to White
- Connect the Green wire to the “Sensor Zone”
- Blue and Brown zone bypass wires are optional

Controller

Field Common

“Sensor Zone” wire

Optional override wires

24V CDM
Simplified Moisture Threshold Programming

SMRT-Y Auto Set Features

1) Saturate the sensor area
2) Set any zone on the controller to water the next morning
3) Initiate the auto-set feature

The controller will automatically set the moisture threshold to 80% of field capacity when the controller initiates irrigation.

Threshold can be manually set and adjusted up or down depending on the site requirements.
Worry-Free Irrigation with Closed Loop Irrigation and Soil Moisture Sensors