A method for precision closed-loop irrigation using a modified PID control algorithm

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Abstract

This poster presents the innovative Script Editor feature of DeltaLINK 3.0 software when used in combination with the new GP2 Logger and Controller. This powerful new Script Editor function gives the user an accessible way to create sophisticated mathematical functions and models that can be applied in real-time to the measurement data collected by the GP2 - providing useful outputs from the combination of different types of measurements and/or multiple sensors. Potential applications are numerous, including areas such as the calculation of evapotranspiration, irrigation control and disease prediction. In the experimental work shown below we have created an enhanced PID controller within the DeltaLINK 3.0 Script Editor - enabling the GP2 to deliver precision irrigation control for a Poinsettia plant. The data collected shows precise control of soil moisture levels and the PID controller responding appropriately to the diurnal cycle. The experimental system also includes water flow and radiation sensors. The GP2 collects data from these sensors and calculates daily totals enabling the relationship between solar radiation and water use to be investigated.

Applying the GP2 to precision irrigation applications

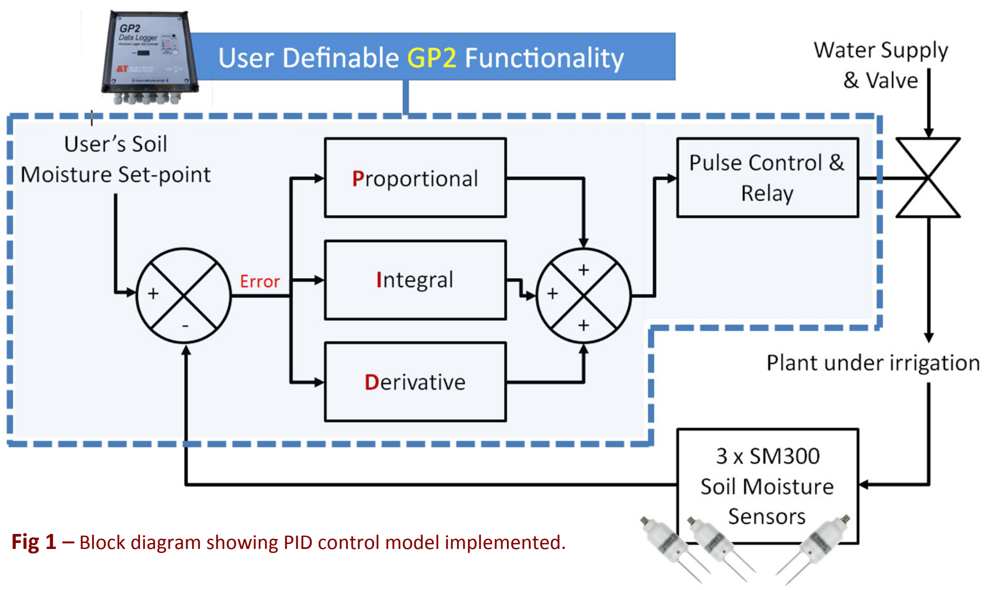

Fig 1 – Block diagram showing PID control model implemented.

- **Proportional**
  - Absolute (measurement) Error relative to the User's set-point
- **Integral**
  - sum of Errors over time,
  - reaches a 'steady-state' level that drives the irrigation flow
- **Derivative**
  - responds to rapid changes in Error
  - used to offset transient high gain Proportional signals
- **Pulse Control & Relay**
  - takes the sum of weighted PID terms and converts it to a duty-cycle for an ON/OFF valve signal
  - pulse frequency or pulse width modulation methods

- **Proportional + Integral + Derivative**
  - each contribution weighted by a coefficient: k_P, k_I & k_D respectively
  - typically aim for 'critical damping' by adjusting coefficients
  - usually difficult to do in theory, requires Laplace transfer functions etc.
  - Zeigler-Nichols often used in practice to start with then optimise

PID irrigation controller implemented using DeltaLINK Script Editor

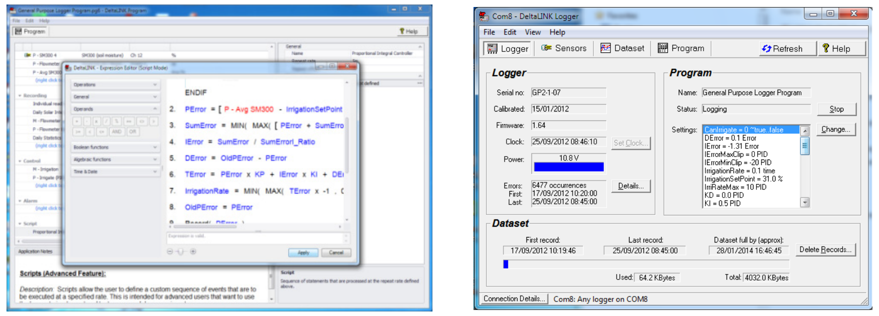

Fig. 2 – Screen shot of PID implementation in DeltaLINK 3.0's new Script Editor for the GP2 (left) and the adjustable program settings (right).

The Experiment

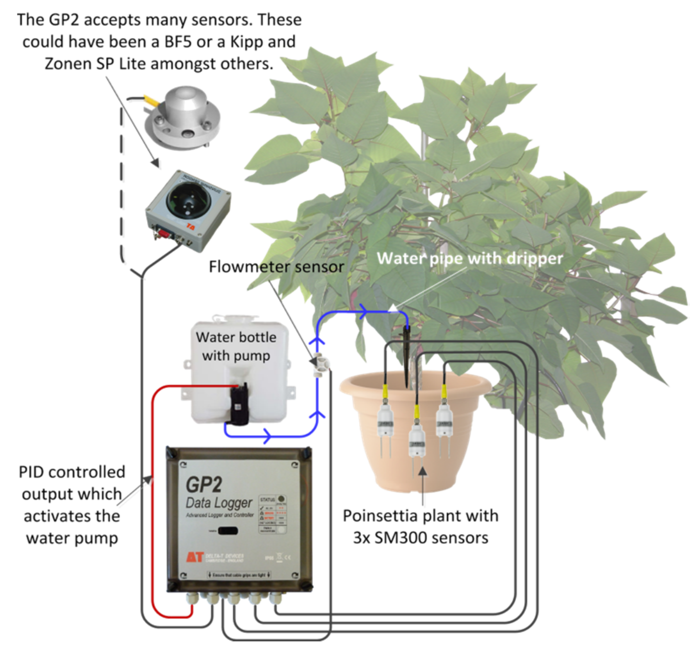

Fig. 3 – Diagram showing the setup of the equipment

DeltaLINK 3.0 and the new GP2 Advanced Logger & Controller were used for running the above experiment. We implemented an enhanced PID controller using the new Script Editor, which allows the user to create their own sequence of operations. We used this ability to calculate errors, integrals and desired irrigation rates. Before starting this plant experiment we tested the PID controller using the updated GP2 simulator - in order to pre-confirm the correct implementation. In Fig. 4 we can see three days data from the Poinsettia plant, where the controller is responding to the demands of the plant through the diurnal cycle.

A soil moisture set point of 31% was used with the average soil moisture measured from 3 SM300 Sensors; see "P - Avg SM300" in Fig. 4. On the sunnier and hotter days (see SP Lite), more water is given to the plant (see "P - Flowmeter") by the PID irrigation controller that also maintained the soil moisture at 31% ±3% with a fixed 2 hour irrigation interval. The solar radiation and water use relationship is shown in Fig. 6.

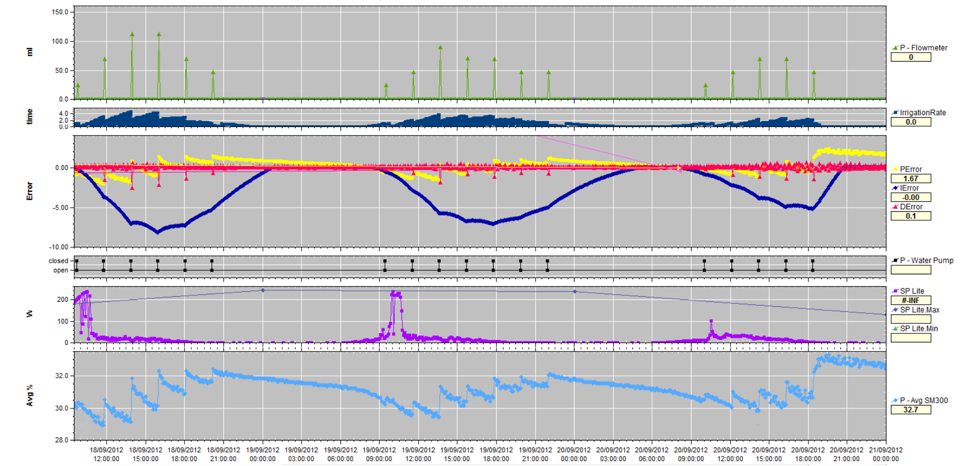

Fig. 4 – The data generated by the PID experiment.

Fig. 5 – The Poinsettia plant used for this experiment.

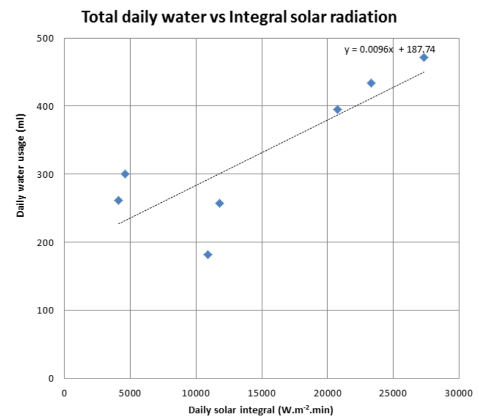

Fig. 6 – Chart showing relationship between water demand and solar radiation.

Conclusion

This experiment demonstrates the effectiveness of the GP2 and the new DeltaLINK software in implementing a successful PID controller based irrigation system. The soil moisture and solar radiation data collected and processed shows that the PID controller responds appropriately to the diurnal cycle - enabling us to investigate the relationship between solar radiation and water use. The sophisticated internal processing involved in this experiment demonstrates the potential for the GP2 logger and controller to be used successfully in a wide variety of complex and challenging real world applications.

References:

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