

Proposal for the Simulation of Rockwell's Enhanced Proportional Integral and Derivative Controls

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The simulation of Rockwell's enhanced proportional, integral, and derivative (PIDE) control of the electric valves of the solenoidal large intensity detector (SoLID) using Rockwell's PLC RSLogix 5000 pre-defined instructions is proposed in this note.

Rockwell's PIDE [1] controls are to be used for the electric valves of the Hall A SoLID magnet [2]. Given the set value to which the valve should be opened, either the Independent Gain Form or the Dependent Gain Form may be used to calculate the output value—the value to which the valve has been opened after an iteration. The iteration stops once the error between the set and the open value is below a prescribed limit.

In the Independent Gain Form, equation 1, each term has separate gains K_p , K_I , and K_D . In the Dependent Gain Form, equation 2, the instruction's algorithm uses the controller gain K_C .

$$CV_n = CV_{n-1} + K_p \times \Delta E + K_I / 60 \times E \times \Delta t + 60 \times K_D \times (E_n - 2 \times E_{n-1} + E_{n-2}) / \Delta t \quad (1)$$

$$CV_n = CV_{n-1} + K_C (\Delta E + K_I / (60 \times T_I) \times E \times \Delta t + 60 \times T_D \times (E_n - 2 \times E_{n-1} + E_{n-2}) / \Delta t) \quad (2)$$

where

CV = control variable,

n = iteration number,

E = error in percent of span,

Δt = update time in seconds used by the loop,

K_p = proportional gain,

K_I = integral gain in min^{-1} ,

K_D = derivative gain in minutes, and

K_C = controller gain.

The terms and nomenclature in the equations are not clearly explained in the manual, especially the delta error term. Further, the manual does not explain how the gain terms' values change after each iteration.

Simulation of both forms of the PIDE instruction will clarify how the calculations determine the output value and how the set value determines the output value.

The software components to be used for the simulation are the following:

RSLogix 5000 to generate the control program using the PIDE instruction to set up configurations and control logic required to mimic current in the magnet's control program,

RSLogix 5000 Emulator to simulate input and output signals,

Factory Talk View Studio to program and create human machine interface screens to allow control and monitoring and to generate the local data archiver to store the data for the set and output valve position values,

EtherIP driver to support module interfaces of Allen Bradley ControlLogix 5000 PLC devices via Ethernet to EPICS IOCs, to interface the EPICS environment with the ControlLogix 5000 PLC, and to convert PLC tags to EPICS PVs,

CS-Studio Phoebebus to create screens to control and monitor the valve simulation, and

Python to analyze the data and generate the plots.

In addition to the simulation, hardware-based testing of the PIDE will be conducted with a PLC chassis instrumented with a controller, a PLC ADC input, a PLC analog output, PLC relay modules, and dummy loads. Figure 1 shows the schematic of the software and hardware tests.

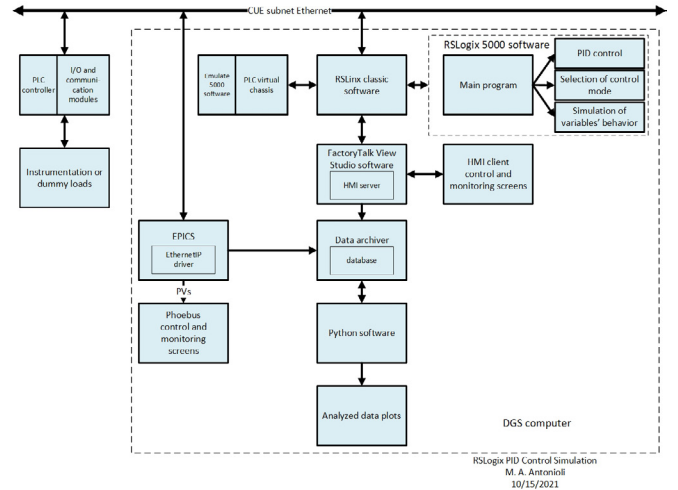


FIG. 1. Proposed simulation for PID controls.

The results of the simulation will provide an understanding of how the output value is calculated and enable an optimum calibration of K_p , K_I , K_D , and K_C used in the PIDE instructions.

[1] *RSLOGIX 5000 Advanced Process Control and Drives Instructions Manual*, September, 2020.

[2] P. Campero, et al., *Controls for Hall A SoLID Magnet Valves*, DSG Note 2021-18, 2021.