COMPARATIVE ANALYSIS OF DIFFERENT MODES OF A PID CONTROLLER USING A HYDRAULIC LEVEL CONTROL TRAINER

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Abstract

Stability is one of the most important criteria in the field of automatic control. The most widely used control strategy in industries is the proportional integral derivative (PID) controller. PID controllers are popular as they can perform robustly in a wide range of operating conditions and due to their functional simplicity. In this work, PID controller's four modes of operation have been compared for providing optimum stability to a hydraulic level control system. It is shown that how P, P-I, P-D and P-I-D controllers change the steady state response of the level control trainer. It is meant to show how one can gain a feature but lose the other.

Keywords*:* PID, hydraulic, controller, automatic, stability

I. Introduction

Feedback is the most basic and commonly used control strategy [1-2]. Through feedback control a desired process condition is achieved and maintained by measuring the process condition with respect to the desired condition, set point, and initiating a corrective action based on their difference [3-8]. For example: Level is the controlled variable. Level in the tank is measured by the sensor/transmitter and signal is transmitted to PID controller. Set point is given through the PID controller and depending on the error between the set point and the measured variable a corrective signal is given to the control valve. Control valve, through the E/P converter. The valve opens or closes according to the signal and the flow of water in to the tank is adjusted. This in turn adjusts the level in the level tank till the level that is controlled variable equals the set point. Thus here PID is acting as feedback controller where the controlled variable is the output from flow transmitter and the manipulated variable is the flow into the tank.

II. Methodology

Pump is used to deliver water from a sump tank to the transparent level controlled tank. Control panel houses the PID controller, pneumatic regulator and is used to make adjustments. The liquid level is measured by a pressure transducer. The transmitter is generally fitted at the bottom of the tank and it measures the head pressure. The pressure is translated into a resulting liquid level. Pneumatic control valves control the flow of pressurized air.

The bypass valve triggered by a spring-loaded mechanism that opens when fluid pressure becomes too high or too low. As long as the pressure is same on both the inlet and the outlet side of the spring, the switch remains closed. But if the pressure build-up iss too much on one side, the spring got compressed, causing the switch to open. E/P converter forms the link between electrical measurements and pneumatic control systems. They also convert the electronic controller outputs into air pressures for operation of pneumatic valves.

III. Experimental Work

The experimental setup used in this work has been shown in Fig.1. It is to be noted here that for tuning the PID controller following steps are to be followed:

1. Observe the level fluctuations for three minutes. If it is not close to the set point then increase the proportional band gradually till the level becomes steady and equal to the set point.
2. Observe the output for three minutes. If the response is very sluggish then decrease the proportional band.
3. When the actual level value comes close to the set point value reduce the integral time gradually till sufficiently fast response is obtained.

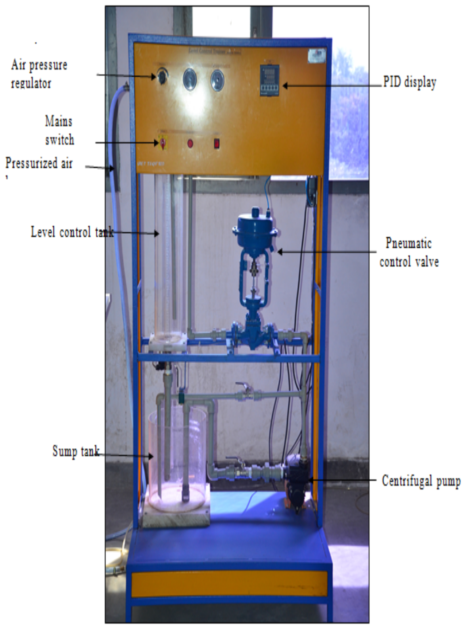

Figure 1: Experimental set-up for P, PI, PD and PID control

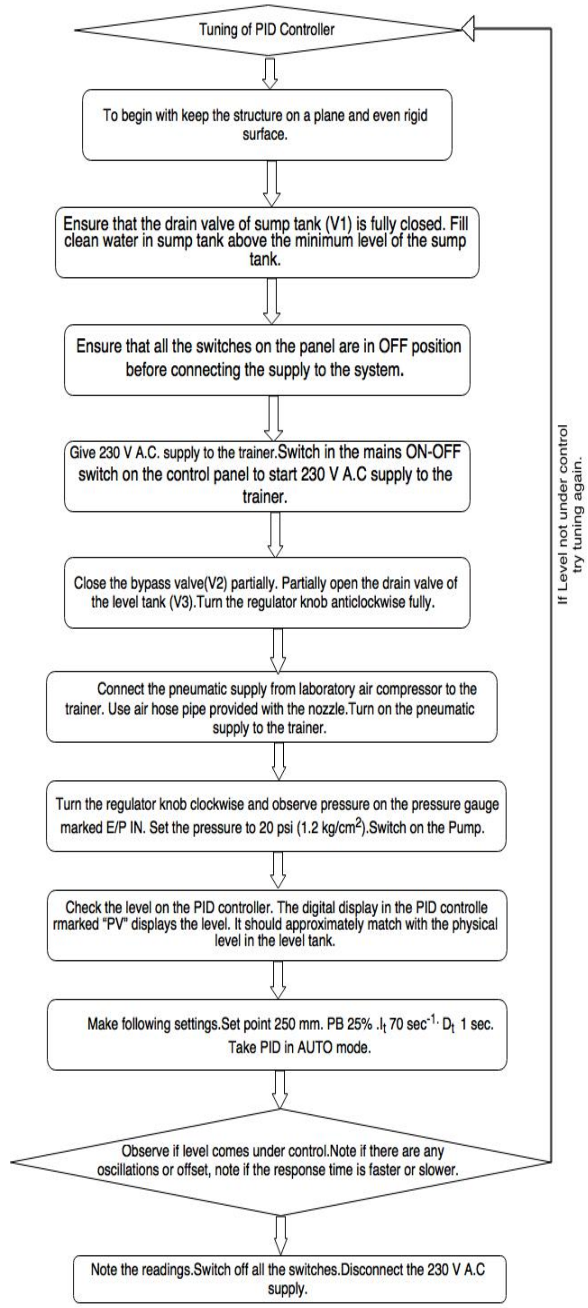

Figure 2: Flow chart showing the tuning procedure

Analysis has been done using the graphing in excel and output versus time plots generated using adaptive neuro fuzzy interference system. It uses a hybrid learning algorithm to tune the parameters of a Sugeno-type fuzzy inference system. The algorithm uses a combination of the least-squares and back-propagation gradient descent methods to model a training data set. Fuzzy logic starts with the concept of a fuzzy set. A *fuzzy set* is a set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership. Fuzzy sets describe vague concepts (fast runner, hot weather, weekend days). A fuzzy set admits the possibility of partial membership in it. The degree an object belongs to a fuzzy set is denoted by a membership value between 0 and 1. A membership function associated with a given fuzzy set maps an input value to its appropriate membership value. The membership functions used in this work have been shown in Figs. 3 to 5.

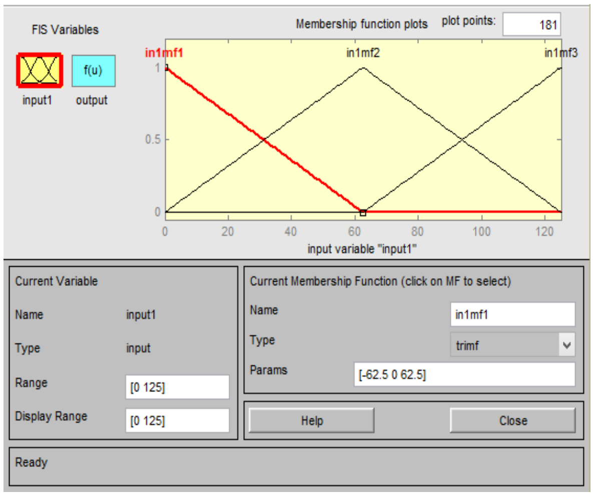

Figure 3. Triangular membership function plot

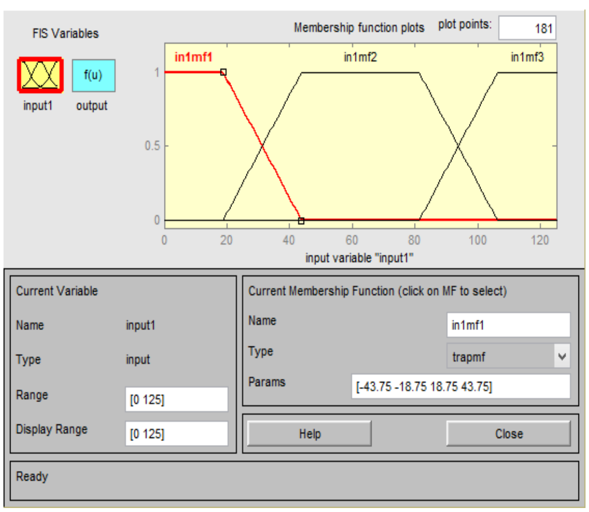

Figure 4. Trapezoidal membership function plot

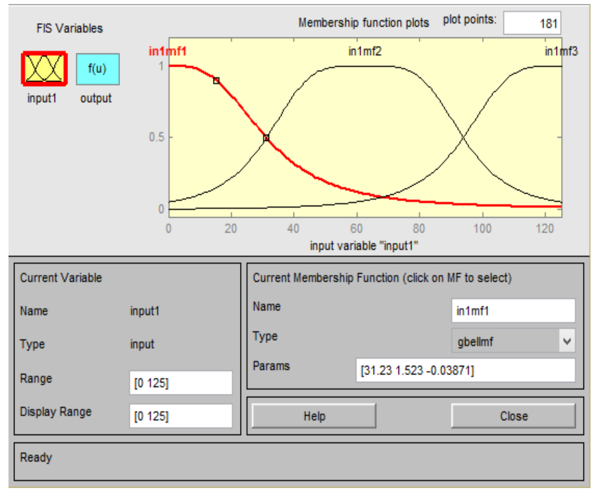

Figure 5. Gauss membership function plot

The generalized bell membership function is specified by three parameters and has the function name gbellmf. The bell membership function has one more parameter than the Gaussian membership function, so it can approach a non-fuzzy set if the free parameter is tuned. Because of their smoothness and concise notation, Gaussian and bell membership functions are popular methods for specifying fuzzy sets. Both of these curves have the advantage of being smooth and nonzero at all points.

IV. Results and Discussion

Numbers of nodes used are sixteen and number of linear parameters in usage are three, number of linear parameters are nine. So total number of parameters are 12. Number of data pairs used for the training are 26 that have been obtained from the data used for plot of PID [25,10, 25].The three fuzzy rules have been used which are predefined. The membership functions are also three and are predefined.

P Controller

P mode control and the characteristics observed are as follows:

1. After certain limit, increasing K_p only causes overshoot.
2. Increasing K_p reduces the rise time.

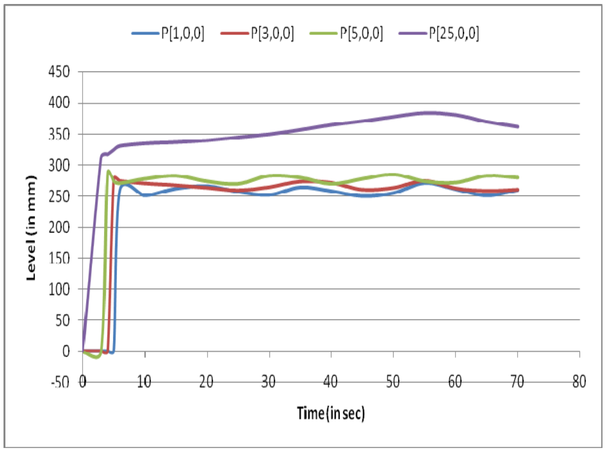

Figure 6. Performance of P controller under different setting

P-I Controller

PI mode control and the characteristics observed are as follows:

1. Integral control reduces steady state error.
2. After certain time, increasing K_i will only increase overshoot.
3. Variation in the level is reduced to much extent by increasing K_i.

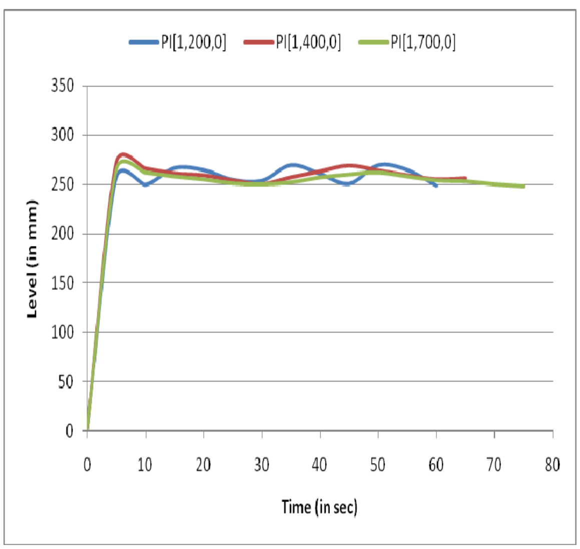

Figure 7. Performance of PI controller under different setting

P-D Controller

PD mode control and the characteristics observed are as follows:

1. D mode is designed to be proportional to the change of the output variable to prevent the sudden changes occurring in the control output resulting from sudden changes in the error signal.
2. In addition D directly amplifies process noise therefore D-only control is not used.

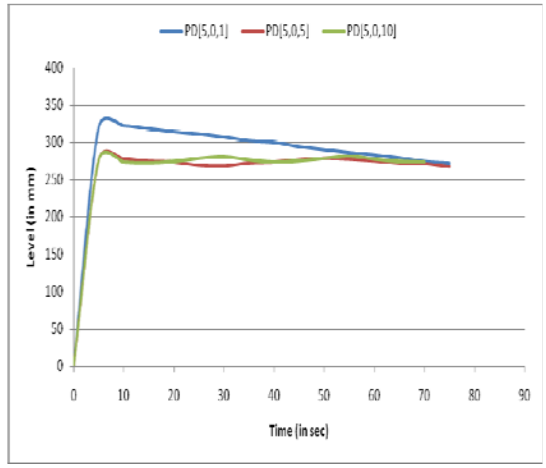

Figure 8. Performance of PD controller under different setting

PID Controller

PID mode control and the characteristics observed are as follows:

1. P-I-D controller has the optimum control dynamics including zero steady state error, fast response (short rise time), minimum oscillations and higher stability.
2. Increasing K_d decreases the overshoot.
3. Increasing K_d reduces the settling time.

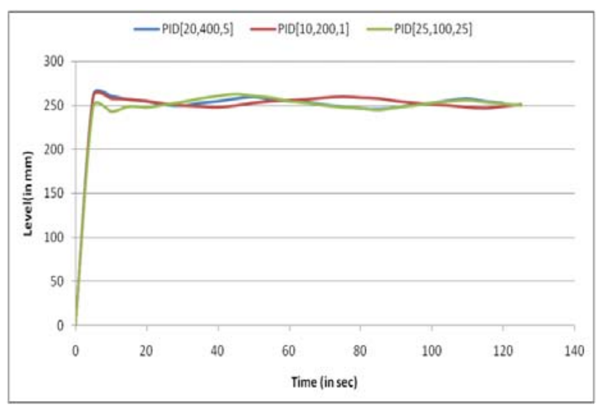

Figure 9. Performance of PID controller under different setting

V. Conclusion

Different types of controllers have been compared against each other in terms of their ability to reduce the overshoot, optimize the rise time, and minimize the steady state error along with higher stability in achieving the water level control. The study concludes that the performance of PID controller is better in all respects when compared with its P, PI and PD counterparts.

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