Using Water Level Control Model to Enhance Learning in Control Engineering Theories

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Abstract

Control theory is one of the most challenging courses in electrical engineering in which pedagogies used in this subject tend to distract students from practical applications. To improve the effectiveness of learning activity, many instructors have adapted physical models of control systems to explicitly demonstrate how to bridge complicated theories to actual implementations. In this study, we develop an industrial water level control model and a STEM education based teaching technique for enhancing learning ability of engineering students enrolled in control engineering theory related classes. The proposed model is used to explain how real industries properly speed up or slow down water flow rate to maintain the appropriate fluid level in the tank by tuning gain parameters in PID algorithm. This method is evaluated by interview. Finally, preliminary results show that target students have positive attitudetoward the proposed model for assisting them in understanding the real mechanics of industrial control water level control, compared to traditional methods which employ only one-way lecture.

Keywords : control engineering, STEM education, water levelcontrol, PID control

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Introduction

Control system engineering is one of the engineering disciplines consisting of many complicated scientific equations connected to several practical applications used in state of the art industrials. Control system courses also contain fundamental concepts which are further extended to other engineering disciplines including mechanical, electrical, computer, telecommunication, and mechatronic engineering. As a result of strong marketing competition which requires disruptive product development, industrial control systems are increasing their complexity which consequently reflects the content of control engineering courses in most universities. To serve industrial requirement, engineering students today are highly expected to know more integrated knowledge of mathematical and actual models of a simple system like washing machines and more elaborate systems such as automobiles, aircraft, and spacecraft. For these reasons, in addition to solely improving the course content, instructors who manage learning and teaching activities in classrooms also require new techniques to promote leaning achievement of this one of the most challenging but prolific courses among other engineering courses.

As proposed in (Sreeja Nag, 2012), science, technology, engineering, & mathematic (STEM) education should increase students' understanding of functionality of technologies and how systems work. Since engineering involves problem solving and innovation which impact economic importance to society, engineering students should develop some of the skills and abilities associated with the design process. Therefore, this work proposes a STEM education based teaching method for promoting learning in part of control engineering theories. Specially, we develop a water level control model used in the classroom to explicitly demonstrate an application of proportional – integral-derivative (PID) control technique. While traditional lectures on this chapter may confuse engineering juniors or seniors, the proposed method moderates the above learning problem and significantly improves students' understanding of the entire design process including PID control theory and how to implement an actual system from mathematical basis.

The rest of this paper is organized as follows. Section 2 explains related control theory for water level control. The design of physical model of water level control system is discussed in section 3. In section 4, the proposed teaching technique is provided. Preliminary results and discussions are given in section 5, and finally, we conclude this work in section 6.

Proportional-integral-derivative (PID) control

The proposed hardware is designed to demonstrate the application of PID controller. We model a nonlinear physical plant as a water level control system. The PID control of a plant is a closed-loop control which is widely used in industry (H. Akyuz, 2011). Most PID controllers are automatically adjusted on site by different methods reported in recent literature(Weider Chang, 2010). Block diagram of the PID control is shown in figure 1.

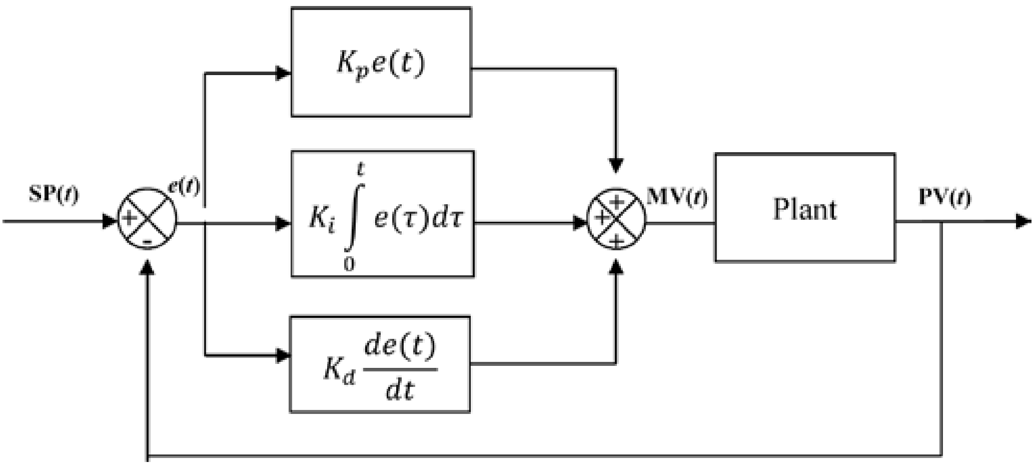

Figure 1. Block diagram of PID control

In figure 1, *manipulated variable*, MV(t) is the summation of output of each of the three blocks, namely P (Proportional), I (Integral), and D (Derivative) controllers. It is seen from the above figure that the P, I, and D blocks have the same input error,e(t) which is the difference between the setpoint, SP(t) and the sensed process variable, PV(t). The equation for the PID controller is given in (1)

$$MV(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt} \qquad (1)$$

where K_p, K_i, and K_d are tuning parameters called proportional, integral, and derivative gains, respectively.

Although there are only three tuning parameters in this controller, finding an optimal operating point of a system is quite difficult. The important requirements for adjusting P, I, and D gains are the response and stability of the system (Ogata, 2010). For example, the overshoot and oscillation may appear at the output, while controller parameters are finely tuned to accelerate system steady-state response. On the other hand, large value of may bring the system to unstable state, whereas small value of the proportional gain may slowdown the system response (Gaing, 2004). Further, since we cannot easily obtain mathematical model of the plant and process, use of computer simulation to search for those parameters can be useful during coarse tuning at initial phase of the design (Suppachai Howimanporn, 2013). However, fine adjustment must consequently be performed to obtain appropriate values of the tuning parameters on site with the actual signal at each process.

With physical model of PID control, teaching PID control in a control engineering course are highly expected to increase students' understanding how to tune PID parameters as explained previously. For our proposed water level control model, students can observe and measure water level in the tank as actual system response with different behaviors corresponding to P, I and D gain configurations. Finally, the developed model is also expected to help engineering students experience the practical approach to boost the performance of PID controllers which are generally used in industry.

Water Level Control Model

In this section, the implementation of water level control model is provided. Our proposed system consists of mechanical and electrical parts. In mechanical part, a dc pump moves fluid into the tank. This part is fully controlled by electrical/control units where tuning parameters of PID algorithms are adjusted through a microcontroller. The electrical unit is also responsible for providing power supply to each unit that requires electric power. In addition, the fluid level sensor converts fluid level, mechanical value, into voltage, electrical value. The sensed voltage is then fed back to the microcontroller as PV(t) of the system. The block diagram of our water level control model is shown in Figure 2.

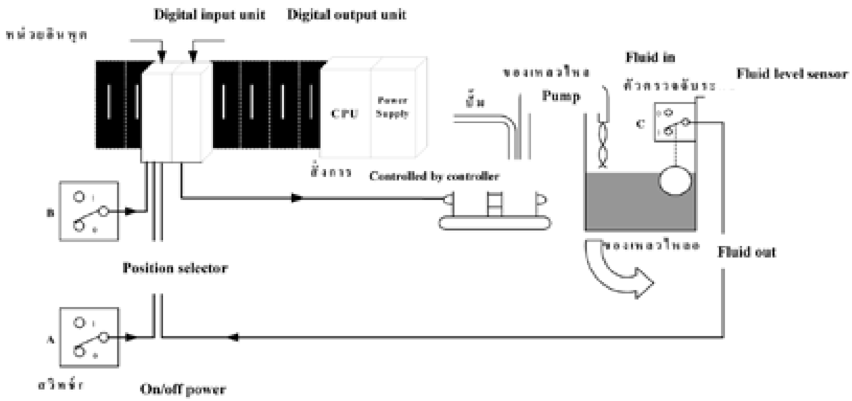

Figure 2. Water level control system

Figure 3 shows the proposed model of water lever control plant with its actual dimension. The 12 V-dc pump pulls water from the lower tank into the upper tank. Fluid in the upper tank can be drained through a brass valve. The LCD display shows voltage value from the sensor corresponding to the level of fluid in the upper tank. This voltage is considered as final response of the system in which we must monitor its behaviors for each PID gain configuration. Moreover, it can be seen from Figure 3 that the size of entire model is so compact that it can be moved easily. Instructors can bring this set to their classroom without large space requirement compared to most experimental sets installed in laboratories.

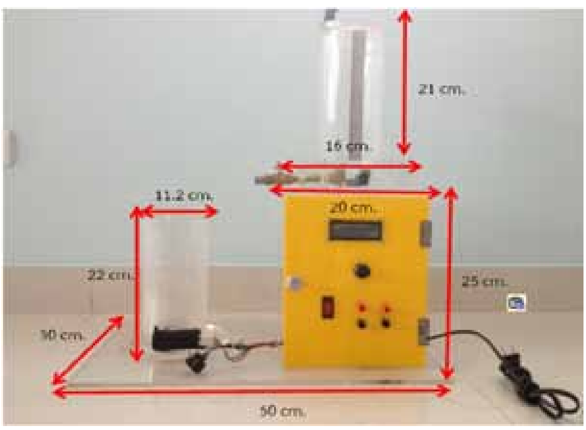

Figure 3. Actual water levelcontrol model

Proposed Teaching Technique

As discussed in section 2, analytically tuning the performance of PID controller is difficult or impractical. Traditional control engineering classes with one-way lecture hardly help student understand the content well. Hence, this model is developed to support students' understanding of real industrial application of PID control. Using the proposed model, target students are assigned to complete following tasks.

1) P (proportional) control

In this task, students are assigned to set the value of water level to 115 mm. Next, the P gain of the controller is varied, whereas I and D gains are set to be zero. Students then record the responses of water level and observe different behaviors of system responses with respect to time until arriving at steady-state as given in Figure 4. Finally, students will discuss specific characteristics of this approach.

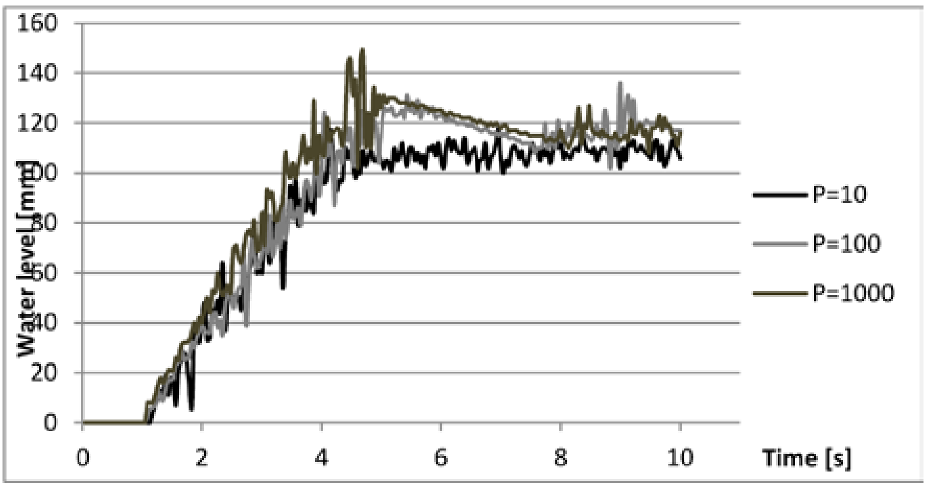

Figure 4. Responses of P control

2) PI (proportional-integral) control

Students repeat their experiment. Yet, in this task, both P and I gains are varied, whereas D gain is set to be zero. Students observe the responses of water level corresponding to P and I gains as shown is Figure 5.

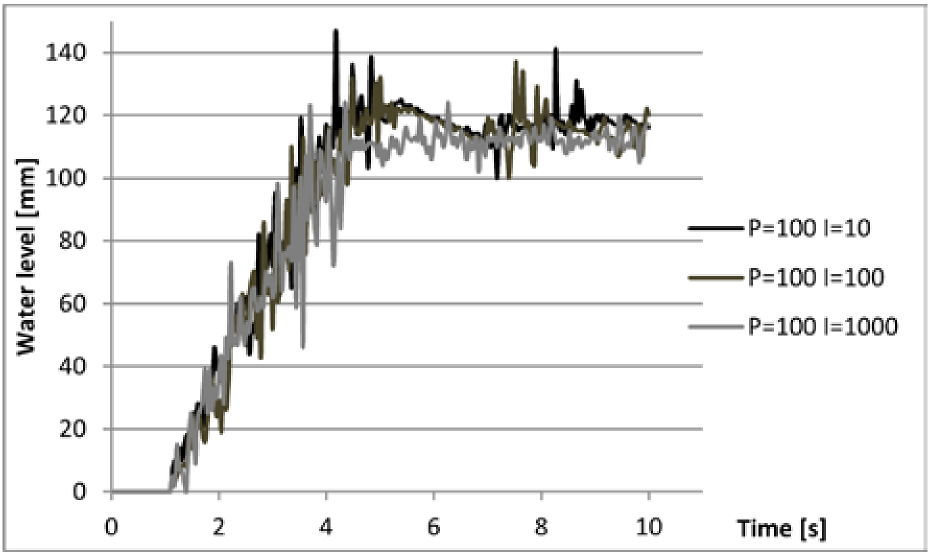

Figure 5. Responses of PI control

3) PID (Proportional-Integral-Derivative) control

In this experiment, students will adjust all P, I, and, D gains and observe the system responses as seen in Figure 6.

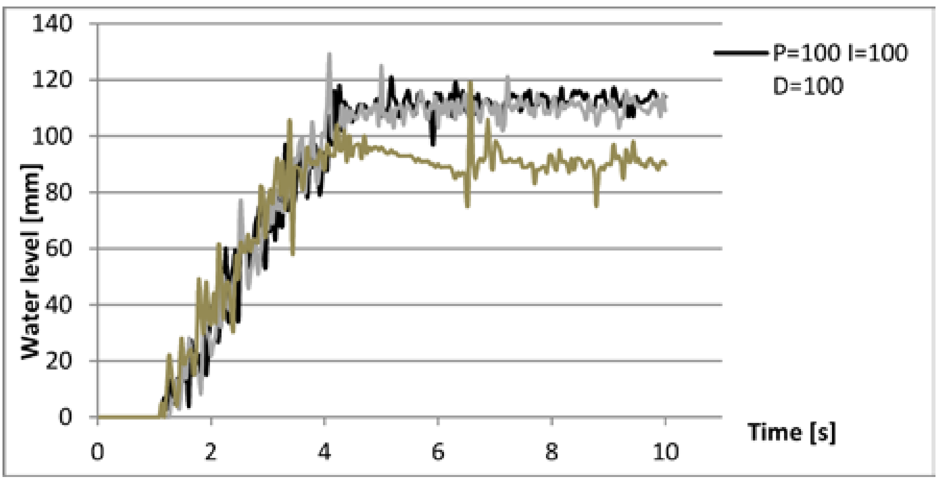

Figure 6. Responses of PID control

Results and Discussions

This project recruited 23 first-year undergraduate students in the Department of Electrical Engineering, Faculty of Industrial Education, Rajamangala University of Technology-PhraNakhon, Thailand to participate in this pilot study. We asked the participating students to reveal their own attitudes about the proposed model, we found that they have positive attitude toward this teaching method which fits with their personalized learning as follows:

StudentA : *"I understand how PID control works from this model"*

StudentB : *"I have just known how PID control algorithm is applied to actual process"*

StudentC : *"It promotes myunder standing of PID control"*

StudentD : *"I have just got how integral and derivative operation can be used in real plant"*

Most target students are interested in this approach of teaching. Most of them said that the water level control model can bridge the theoretical point of views, which is typically laid on almost all of the pages of control engineering textbooks, to the practical applications in which they will experience in their future professions.

Conclusions

A water level control model isdesigned topromote learningand teachingoutcomes in control engineering theories and their applications.From the proposed model, students can explicitly observe the responses of the plant employing PID control algorithm, one of the most crucial parts in control engineering course, widely used in today industry. From the preliminary results done by interview, this technique can help students integrate the theoretical PID control conceptswith the practical implementation. Most target students also have positive attitudes toward the use of this proposed method in control engineering classroom.

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