Experimental Research of Intelligent Multivariable 2-DOF PID Control System For DCS

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Abstract—Process systems such as the raw water and chemical injection line in purification, the flow line of the waste water system, and the feed water, or the circulation system of a power plant system must be controlled accurately, because the system's performance and the energy saving rate in the whole system depend on the control method and precision.

Generally, a PI controller is used in these systems, but it is very difficult to find an optimum parameter for the controller, because of the coupling action among loops and the disturbance in the system loop. There are few experimental systems or educational courses for such processes.

This paper introduces an experimental method and educational course into the curriculum, to build up effective instruction of this complicated multivariable porcess system. Also, this paper proposes a new control method that changes the fluid system of a multivariable control loop and applies a NN-Tuning 2-DOF PID controller to experimental equipment. The results could have an impact on the educational method used for experiments. The simulation and experimental results that are acquired in the parallel process represent a satisfactory response against a disturbance and a change of setpoint.

Keywords— Artificial control, Bio tuning, Flow control, 2-DOF control, multivariable DCS control.

I. INTRODUCTION

THERE has been growing interest in applying an intelligent technology, such as fuzzy logic, neural network, and genetic algorithms to process control [2], [5]. These approaches have significant benefits for some fields. However, engineers or managers in industrial fields are often reluctant to utilize new intelligent control techniques. This may be due to the lack of stability and performance, reliability problems in the actual system, or a lack of understanding of the potential of intelligent control systems used by field engineers [3].

In some universities, there is a pessimistic attitude towards applications-directed research and education in these particular areas. This is why conventional control theory has been used in the curriculum in many university courses, during the past 30 years. When revising curriculum for control engineering programs, in order to introduce an intelligent process control, it is necessary to prepare educational content and theory at least three or four years in advance. Also, substantial changes adopted in other universities should be taken into consideration. It is very important for university educators, including professors and assistants, to recognize the importance of incorporating educational content in the area of intelligent control. For the last three years, under these challenging conditions, it has been the goal of the Department of Instrumentation and Control in the HNU (Hanbat National University) to adopt a more realistic approach in both lectures and laboratory courses, based on real plant experiences. The project has been created by the fund of KEPCO (Korea Electrical Power Company) to bring intelligent process control technology into the regular curriculum. The goal of the project was to prepare an educational course (including an experimental system and textbook) which differed from the existing approaches taken towards intelligent process control.

This paper refers to a laboratory course which includes an experimental system for intelligent process control. Of course, there many types of experimental equipment for process control which exist around the world. An instructor might be hesitant to introduce new concepts into the regular curriculum, as there may be no detailed descriptions about an experimental system. There may also be incompatible description between textbook and experimental equipment.

In addition to providing educational material for process control, this research can provide an opportunity to implement tuning by a neural network on an experimental system..

II. BIO-INSPIRED DCS PROCESS CONTROL

A. Process Control for DCS

Process control systems, such as the raw water or the chemical injection lines used in purification, waste water treatment lines, power plants, chemical reactors, and heat exchangers are composed of many kinds of devices and fluid lines to mix, purify, and operate the qualified product. Many of these systems have a parallel fluid control system. These systems are composed of a multivariable system with two inputs and two outputs. Since the electrical power or energy consumed in these systems comprises a great part of their load facilities, as an engineer, it is very important work to study an optimal control method for these complicated systems for saving energy or ensuring the quality of product. Several methods can be used to effectively control the fluid process system. The controller gains in these processes must be tuned in order that the process can be controlled within the setting point or the desired value. However, many factors should be taken into consideration to control the multivariable fluid system, because control performance is determined by the structure or the control algorithms of the controller used in these systems [3], [4], [5]. Up to this time, a very general scheme has been used to accomplish the desired control function in these systems. It is composed of a cascade structure with a master controller and a slave controller. This method regulates the flow of injector (or cold water) in accordance with the main process (or hot water)

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demand. The main flow is controlled by the master controller, while the chemical injector flow stream is controlled in a fixed ratio to the main flow by the full scale ranges of the measuring systems. In order to control this parallel fluid system effectively, the flow distribution status, average velocity, viscosity, pipe diameter, and other factors must be considered. However, it is difficult to control with this controller, because up to the present time, a single loop PI controller has been used in these systems. There are additional problems in that when using only a PI controller, it cannot reject the disturbance of the fluid lines or the measuring systems [6].This research applies a 2-DOF (Two-Degrees of Freedom) PID controller to the parallel flow systems. The 2-DOF PID controller is tuned by a neural network, and its learning algorithm used a back propagation method. The detailed description is given in Section III.

B. *Tuning Problem in DCS*

Proportional-Integral-Derivative (PID) controllers have been widely used, due to their simplicity and robustness. They have been used in chemical process control systems, power plants, and electrical systems. Their popularity is also due to easy implementation in hardware and software.

However, since the response of process depends on the gain P, I, D, the linear PID algorithm might be a problem when dealing with processes or plants with complex dynamics, such as large amount of dead time, inverse responses, and highly nonlinear characteristics. Moreover, industrial experience is required for a higher automatic tuning, because the PID controller is usually poorly tuned in practice [1], [3], [4].

There are many well known PI and PID tuning formulas for stable processes that are suitable for auto-tuning and adaptive control. However, PID tuning formulas for unstable processes or complex plants are less common.

Many sophisticated tuning algorithms have been used to improve the PID controller work under such difficult conditions, since the control performance of the system depends on the parameter gains. In many cases, they are manually tuned through a trial and error procedure and the derivative action is switched off, since it is difficult to tune.

A process control system is often subjected to changes, due to a variety of uncertain sources. For instance, a small deviation from normal operating conditions may have disastrous effects on a system, and performance characteristics such as stability and robustness may need to be re-examined as the degree of complexity and uncertainty increases.

A great deal of effort has been directed towards finding the best choices for the controller gain, and integral and derivative time constants for various process models [6], [7], [8], [9]. In many cases, they are based on the performance index for the PID controller parameter tuning.

The criterion used to keep the controlled variable response close to the desired closed loop response has been widely accepted in chemical process industries, because of the PID controller's simplicity, robustness, and successful practical applications. In order to obtain optimal gain for a plant, the tuning condition of the plant must be taken into consideration. This is because the controller gain does not behave as expected as the result of disturbance. However, current tuning methods yield derivative and integral time constants that are independent of the closed loop time constant, in an actual plant. Also, current tuning methods only tune PID parameters for a restricted class of process models, by trial and error procedures. Therefore, there is no general methodology for tuning arbitrary process models. Further, because the desired closed loop time constant obtained by an engineering approach method or conception, i.e. the response characteristic of a plant, depends on only the tuned PID parameters, an effective educational methodology for intelligent process control needs to be conducted on a variety of practical equipment. Also, several examples should be provided to demonstrate the method and also be used to compare results with alternate tuning methods.

III. EDUCATION PROGRAM FOR INTELLIGENT DCS CONTROL

A. *Curriculum For Intelligent DCS Control*

In order to enhance understanding of the IPCL (Intelligent Process Control Laboratory) course, this paper briefly describes the curriculum of the Department of Instrumentation and Control (DIC) in the HNU. To ensure the proper relationship between courses, the curriculum has been reviewed and changed every year, during the last four years (1996-1999). Currently, curriculum is classified into four categories including Basic Field, Related Field (Mechanical and Pneumatic Field), Programming Field, and Process Control Field. The detailed topic list at the undergraduate level includes 17 graded courses, as in Table 1. All freshman students should register in the introductory course. However, from the second year, all students should register in the major field, and include four subjects in each semester.

In the graduate course, all students must register in the courses listed in Table 2, with the final course being a project. In addition to completing the courses, students should write a master thesis about their special topic, at the end of the program. The results should be published in a related internal journal or conference publication, as a final requirement.

B. *Curriculum Implementation For Intelligent DCS Control*

For the purpose of devising effective education for Intelligent Process Control, the courses are classified into the Related Field and Programming Field. The Related Field includes all courses except the main courses, and provides a variety of information about current technology on intelligent process control system, before actually introducing it into the curriculum. In this course in the Programming Field, an opportunity is offered for students to improve their control theory or programming abilities through the use of a variety of computer language in this course.

C-language and MATLAB language are mainly served, but BASIC language is also used for part time, evening class students. This is because some part-time students already have good skills in special program languages.

In the Intelligent Process Control Course, there are four courses, including Sensor and Industrial Measurement, Process Instrumentation, Process Control and Laboratory, and Plant Control and Laboratory. At the graduate level, there are the six courses described in Table 2; content is composed of the more advanced topics.

Table 1 Course list at the undergraduate level

Course title	Recommended Level
- Introduction to Measurement and Control - Basic Programming	Freshman
- Sensor and Industrial Measurement - Programming and Laboratory for Automatic Control - Pneumatic Equipment - Digital Logic and Laboratory - Microprocessor and Laboratory	Second year
- PLC and Plant Control - Signal Processing and DSP program - Digital Logic and CAD/CAM - Computer Interface and Laboratory - Measurement and Laboratory - Precision Measurement and Laboratory	Third year
- Process Instrumentation - Process Control and Laboratory. - Plant Control and Laboratory (Project) - Image Processing and Laboratory - Industrial Management	Final year

Table 2. Course list at the graduate level

Course title	Recommended Level
- Advanced Process Control - Advanced Instrumentation - Intelligent Control - Modern Control - Control Device and Machine - Special Project	None

C. *Lecture-Laboratory Course*

Lecture-Laboratory courses, for example the Process Control and Laboratory in the final year as shown in Table 1, offer laboratory courses and lectures which include running the existing experimental equipment for Intelligent Process Control. The main experimental equipment is as follows: Data Acquisition Board, PLC, Experimental equipment for various sensors, Commercial S/W for DCS, pH control experimental equipment, Single flow control equipment, Parallel flow control equipment, Turbine control equipment, and DCS facilities. The basic course structure is as follows:

- Week 1 (Introduction): Exercises for this laboratory require the student to use MS Windows, SEMTOOL (control S/W: similar to MATLAB), and CIMON (commercial S/W for process plant control made in Korea), and to acquire a basic understanding of equipment used for experiments.
- Weeks 2-4 (Plant Design): Students are introduced to the capabilities of the commercial plant control S/W. Students should design the structure of the plant or the equipment to be controlled, using graphic functions of the CIMON, and then also simulate and analyze the plant. Of course, procedures include accessing the actual signal from the PLC or sensors.
- Weeks 5-7 (Plant Control by Equipment): For the first time, students gain experience through implementation of the actual process. Several types of equipment are prepared for this course. Students are required to implement and tune both the PID controller in PC and the actual PID controller.

Weeks 8-10 (Project in Intelligent Process Control): Students carry out projects which go beyond the first eight weeks of the course, in terms of methods applied and control objectives. A variety of intelligent control (graphic and plant design) techniques including fuzzy, expert, neural, and genetic algorithms are introduced on the experimental equipment using their program and the programmable logic controllers. PLC units developed by a manufacturer in Korea are offered.

- Weeks 11-16 (DCS Operation): All students must operate on the DCS (Distributed Computer System) using a plant module they have designed with the commercial plant S/W (CIMON). They must also obtain operating data from the start-up, running, and stop procedures. In addition, detailed discussions are conducted during the last week of the course.

D. *Lectures*

Several lectures are given in the lecture room adjacent to the Laboratory. These include the following:

- C-Code Programming for Intelligent Control
- Artificial Intelligence
- Automatic Control for Industrial Field
- Pneumatic Control
- DSP Architecture
- Signal Processing.

IV. LABORATORY EQUIPMENT For Intelligent DCS Control

A. Importance of Intelligent Control in DCS

For actual implementation and experimentation of conventional and intelligent control, the chemical mixing process control plant and DCS are used. This experimental equipment consists of two tanks, two liquid-level measuring devices, two temperature measuring devices, two control valves, and one heater (see Fig. 2). The liquid level in each tank is measured by a level transmitter, attached to the side of the tank. Temperature measurements are made via temperature transducers mounted in the reaction chamber (where hot and cold liquid is mixed) and in the hot tank. An AC pump is used to remove liquid from the reaction chamber, while two pneumatic control valves control liquid from the hot or cold tanks to the reaction tank. These devices (AC pump, heaters, and control valve) can be tuned on or off independently, making up five of the plant's inputs. The flow rate of these liquid lines can be varied independently with a pneumatic valve by changing their supply signal, 4-20mA. As the objective of this experiment is to try the implementation of intelligent process control on the actual plant, its result is compared with the result of the conventional PID controller tuned by the Ziegler-Nichols method.

B. pH control equipment

As the control of pH is a commonly encountered problem in the process industry, neutralization can be an integral part of many processes such as waste water treatment, the soap industry, ore flotation, biotechnological processing, and pH sensitive processes. Of the many applications of pH control, neutralization in waste water treatment is by far the most important task. Also, it is usually one of the most difficult control problems because of the “S-shaped” characteristic curve, with the steepest slope at the neutralization point, which makes it a highly nonlinear process.

Fig. 1. DCS overview picture in experimental

If a PID type controller is applied to these processes, it is a well known fact that the control result is often unsatisfactory, due to its poor tuning method. This course offers information which demonstrates the importance of a pH control technology in the actual process, through the use of the equipment. Students compare the results of the manufactured controller with the results obtained by the controller, which they have programmed.

C. Parallel flow control equipment

This equipment is used for experimentation with the flow characteristics of the parallel flow system, such as power plant and wastewater treatment, and the purification process. Fig. 2 shows the photograph of this equipment. A detailed description is given in Section V.

D. Heat exchange equipment

When heating or cooling a liquid, it is a physical fact that time is required to transfer energy from the source to the material being heated. Since many industrial processes include the heating or cooling work in process, it is very important to determine the system equation for all system devices (including heat transfer and storage) to obtain a satisfactory control result. However, it is not easy for students to determine the equation for that system. The purpose of this equipment is to inform students of the time delay, response characteristics, and the energy balance relationship of the liquid process. This will enable students to observe each parameter effect in the PID controller. During the final step, students compare the results obtained by the conventional PID controller with the results obtained by intelligent tuning methods. At the graduate level, more detailed experimentation is completed and included in the Master’s theses.

E. Software for experiments

This course offers the following software which provides information on the control algorithms and programming technique in the process control:

- **PLC S/W and C Code** This S/W is given to enhance understanding of the basic concepts about control software language used in the industrial field. The PLC S/W is the commercial product, but students must program the proper C code for plants in which they design a process or equipment. Also, students should communicate with the PLC.

Fig. 2. Parallel flows control equipment.

- Simulink and DSPACE
After completion of the course using the PLC and C codes,

all students will advance to the next course. This will involve analysis of plants or equipment using a Simulink and DSPACE board. Part of this procedure is illustrated in Section V.

- CIMON

This commercial software was developed by a small-scale software company in Korea, in 1995. It can be used for control of the actual plant controls, such as chemical process, power plant, and waste water process. It serves as the basis for the students' experiments. Each student should design a plant which includes conception of and experimentation with the operating status of the designed plant, through connection with a PLC in the given time frame. Through this course, the student is able to learn application of the PLC, and the usage and characteristics of commercial software for the actual plant.

V. Structure Of Multivariable 2-DOF PID Control System

A. Experimental Equipment

The experimental system used in this paper has a structure as shown in Fig. 3. The hot water temperature in the heat exchange is controlled through the parallel flow regulation. Each flow is regulated by a pneumatic control valve, and two magnetic flow sensors are used for flow rate measurement. The controller is multivariable, and has two inputs and two outputs. The detailed description is given below.

B. Structure of the 2-DF PID controller

If the conventional PID controller is used in the parallel flow system with a coupling action, the ratio of main flow (or hot water) to injector flow (cold water) is determined by the controller gain. The interaction in both flow lines is achieved by the fluid dynamic equation which includes the controller structure. For a good control results, a coupling transfer function is required in both flow lines. However, it is very difficult for engineers to obtain the dynamic equation of the parallel fluid line, since a strong mathematical background and engineering experience are required. Therefore, it is very important to have a design that will achieve a good control result. This paper focuses on the application that will achieve a 2-DOF PID controller, which is tuned by a neural network, to the parallel flow system, as in Fig. 4. Fig. 4 (a) illustrates the structure of the controller with a neural network. To facilitate easy implementation for the students' experiments, the transfer function for a PID controller is given during the experiments. In this paper, only the example of a 2-DOF PID controller is described. If transfer function, manipulated value, and set point are given as G(s), PV(s), SV(s), respectively, the change of set point in the 2-DOF PID controller is given in the following equations:

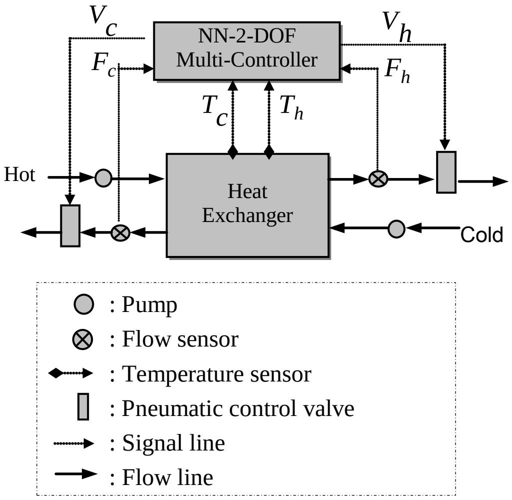


Fig. 3. The experimental system with a NN-2-DOF multivariable controller for the heat exchanger.

$$G_{pv}=\frac{K_p\left(1+\frac{1}{T_i s}+\frac{\gamma T_d s}{1+\eta T_d s}\right)+G(s)}{1+K_p\left(\alpha+\frac{1}{Ts_i}-\frac{(\alpha-1)(\beta-1)}{1+\beta T_d s}\right)+\frac{\gamma T_d s G(s)}{1+\eta T_d s}}sv(s) \qquad (1)$$

On the other hand, in response to a disturbance, the output of the 2-DOF PID controller is given as:

$$G_{pv}=\frac{G(s)}{1+K_p\left(\alpha+\frac{1}{Ts_i}-\frac{(\alpha-1)(\beta-1)}{1+\beta T_d s}\right)+\frac{\gamma T_d s G(s)}{1+\eta T_d s}}D(s)\,. \qquad (2)$$

The deformed numerator is shown in the following equation:

$$RV(s)=G_{pv}(s)+G_{dv}(s) \qquad (3)$$

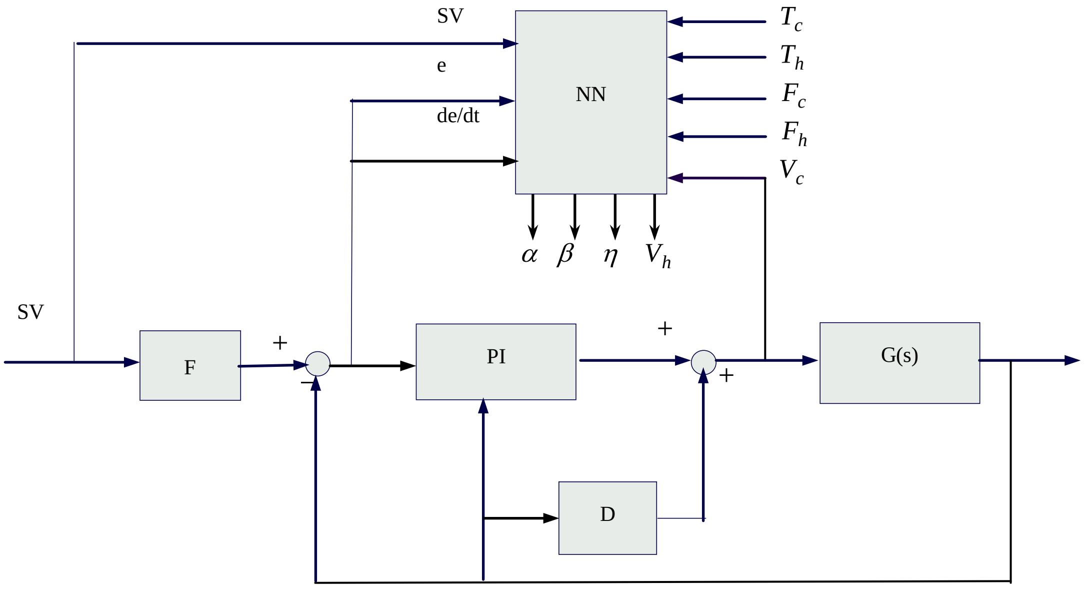
C. Tuning of the 2-DOF PID controller

The ultimate method, the Ziegler-Nichols method, has been used for the tuning of the 2-DOF PID controller. This paper uses the back propagation of a neural network for the tuning of the 2-DOF PID controller. It avoids the adoption of a neural network with a complicated structure, to facilitate the understanding of students and the ease of experiments. Fig. 4(a) illustrates the architecture of the 2-DOF PID controller with a neural network used for the experiments, and Fig. 4(b) represents the structure of the applied neural network.

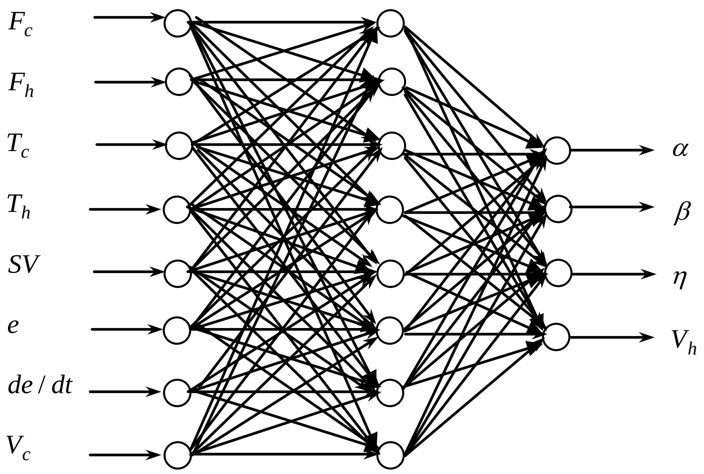
Table 1. The initial coefficient value for a neural network tuning.

Parameter	Value
Kp	1.15
Ti	250
Td	0.5
α	0.7
β	0.1
η	0.4

The neural network has reference signal SV, e, $\frac{de}{dt}$, T_c, T_h, F_c, F_h, and V_c as inputs, the parameter α, β, γ for two degrees of function of the 2-DOF PID controller, and



a) 2-DOF PID controller tuning with a neural network.



b)) Structure of a neural network

Fig. 4. Structure of a multivariable 2-DOF PID of the parallel flow control system by a neural network tuning method.

the output V_h of the controller as the tuning output.

A number of hidden layers can be adjusted by the student, for experimentation. The neuron equation is given by equation (4), and the sigmoid function is defined as a logistic function of equation (5), respectively.

$$y_i(t) = f\left(\sum_{j=1}^{m} w_j x_j(t) + b\right), \qquad (4)$$

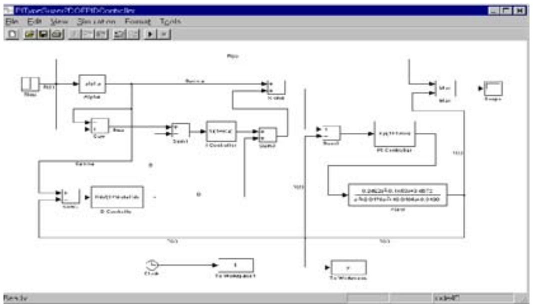


Fig. 5. Implementation using the Simulink.

$$f(x) = \frac{1}{1+e^{-\lambda x}} \qquad \frac{dx}{dt} = \lambda f(x)(1-f(x)). \qquad (5)$$

The network weights are minimized by the following performance index:

$$P(w) = \frac{1}{2}\left(\sum_{j=1}^{n}(d_i - y_i)^2\right) = \frac{1}{2}\left(\sum_{j=1}^{n}(d_i - w^T x_i)^2\right). \qquad (6)$$

The initial tuning coefficient is given in Table 1. If the input signal is introduced to the network, the neural network learns the error to the target value and then regulates α, β, η, and V_h. So, the parameter is tuned as a proper value. A

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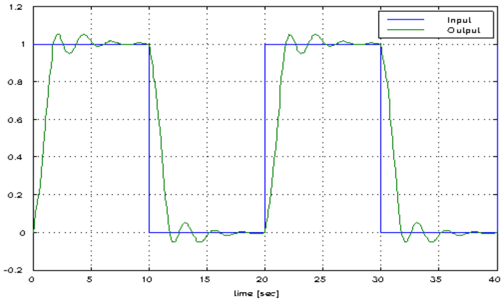


Fig. 6. Tracking response by the 2-DOF PID controller.

VI. RESULTS AND DISCUSSION

A. Simulation Results by the Simulink

Fig. 5 represents the Simulink structure of the feedforward type of 2-DOF PID controller, and Figs. 8-13 are the simulation results. Fig. 8 is the desired response in this experiment, and its pole and zero are as the follows:

P1=-1.0081+3.1416i, P2=-1.0081-3.1416i-0.0315

Z1=0.2941+3.7304i, Z2=0.2942-3.7304i.

Fig. 6 illustrates the tracking performance of the 2-DOF PID controller in relation to the rectangular wave. There is an overshoot at the beginning of the tracking procedure, but the tracking result is good.

Fig. 10 is the response to the variation of parameter α. If α is larger, the overshoot is smaller. Fig. 8 shows a response when parameter β changes at α=0.4. If β is larger, the overshoot is lower.

Fig. 9 is the response when η is changed from 0.1 to 5. If its value is larger, the overshoot is smaller. However, its variation affecting response is very weak. Fig. 10 is the simulation result of the robustness of the 2-DOF PID controller to a white noise. Even if there is intensive white noise, the controller tracks the step response very well.

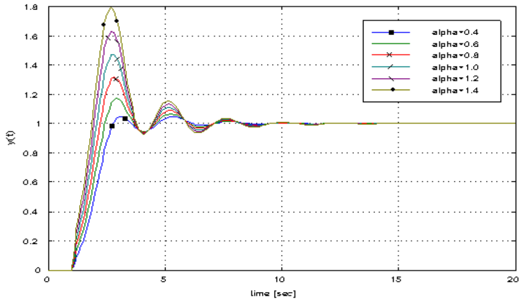
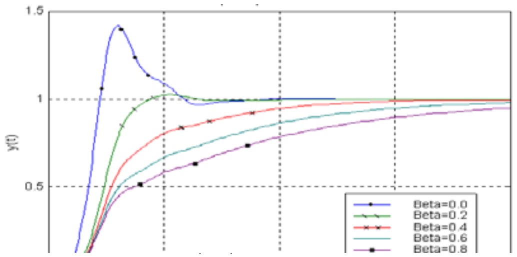


Fig. 7. Step response via α variation.



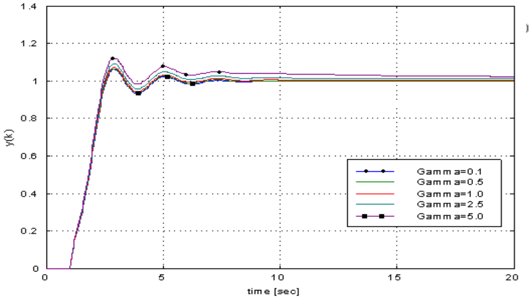


Fig. 9. Step response via η variation.

B. Experimental Results by the Simulink

Figs. 11-17 represent the results performed on the experimental system of Fig. 3. Fig. 11 and Fig. 12 are the response results to the variation of parameter α. Figs. 13-15 are the responses to the variation of β parameter. Fig. 11 shows a full screen of the digital oscilloscope. If α is larger, the overshoot is also larger. Also, in the case of β, the results show a similar characteristic to the simulation, but its value is larger than in the case of the simulation. In Figs. 16-17, the effect of the variation of η is weak, but its curve pattern is similar to the simulation.

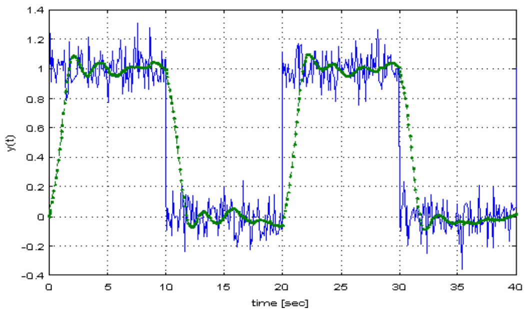
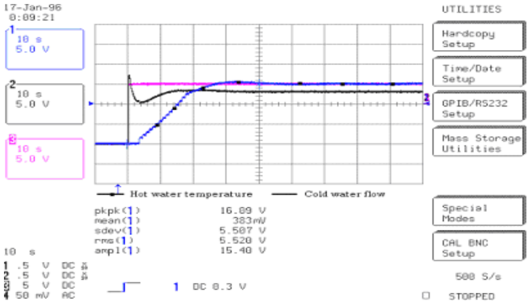


Fig. 10. Step response to a white noise

[: noise (blue), - -: response (green)].



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pkpk(1)     16.09 V
mean(1)       383mV
sdev(1)     5.507 V
rms(1)      5.520 V
ampl(1)     15.40 V
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10   s
1  .5   V   DC
2  .5   V   DC
3   5   V   DC
4  50  mV   AC
                  1   DC 0.3 V
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Fig. 11. The response to α=6 using the Simulink at K_p =2.3, T_i =0.15, T_d =0.1, β=1, η=1.

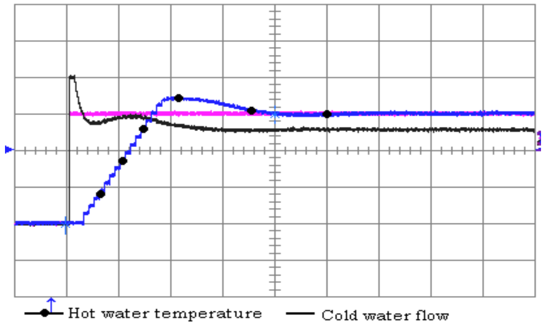

Fig. 12. The response to α=9 using the Simulink at K_p =2.3, T_i =0.15, T_d =0.1, β=1, η=1.

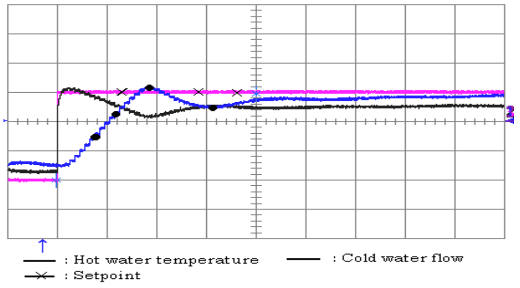

Fig. 13. The response to β=0.1 using the Simulink at K_p =2.3, T_i =0.15, T_d =0.1, α=0.4, η=1.

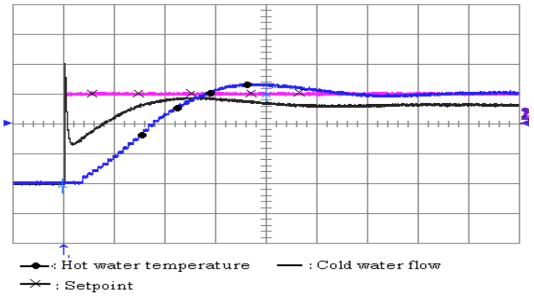

Fig. 14. The response to β=3 using the Simulink at K_p =2.3, T_i =0.15, T_d =0.1, α=0.4, η=1.

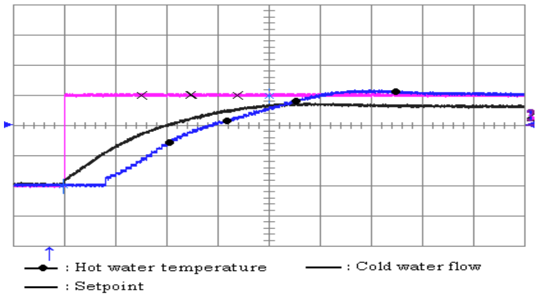

Fig. 15. The response to β=7 using the Simulink at K_p =2.3, T_i =0.15, T_d =0.1, α=0.4, η=1.

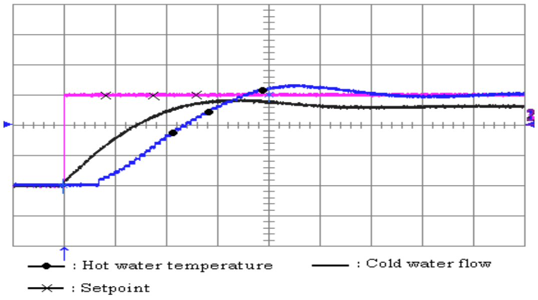

Fig. 16. The response to η=1 using the Simulink at K_p =2.3, T_i =0.15, T_d =0.1, α=0.4, β=0.7.

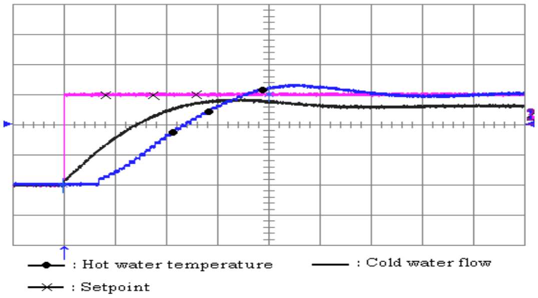

Fig. 17. The response to η=10 using the Simulink at K_p =2.3, T_i =0.15, T_d =0.1, α=0.4, β=0.7.

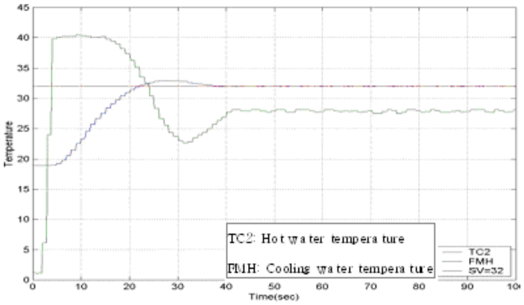

Fig. 18. The response to α=8 using the PLC and C code at K_p =5.2, T_i =0.35, T_d =0.01, β=1, η=1.

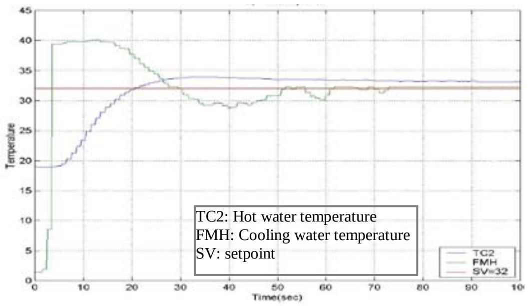

Fig. 19. The response to α=13 using the PLC and C code at K_p =5.2, T_i =0.35, T_d =0.01, β=1, η=1.

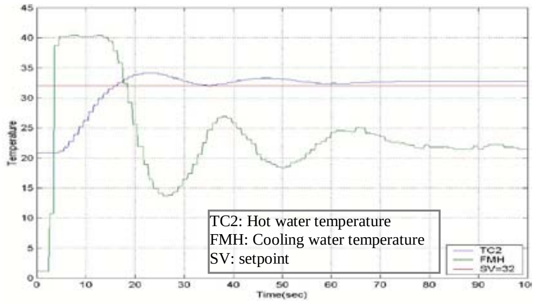

Fig. 20. The response to β=2.4 using the PLC and C code at K_p =5.2, T_i =0.35, T_d =0.01, α=1, η=1.

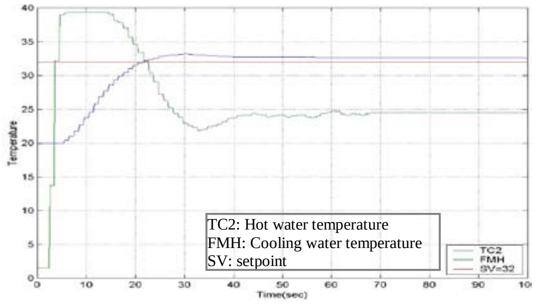

Fig. 21. The response to β=3.8 using the PLC and C code at K_p =5.2, T_i =0.35, T_d =0.01, α=1, η=1.

C. The result of the PLC and C program

Figs. 19-21 shows the result achieved, using the PLC and C program. The effect of the variation of the parameters α, β, η has a similar characteristic to the variation of the Simulink, but these experimental values are larger than those of the simulation.

D. The result using the DCS

On the other hand, Figs. 23-24 show the experimental result on the DCS, using the designed NN-Tuning 2-DOF PID controller. Its result has a somewhat different shape, since the structure of the DCS process is different. However, the results come after the settling point.

Also, responses observed by the change of α, β, η have similar trends as those of the simulation. A more detailed description will be covered in another paper, in the future, since a comparative illustration of the experimental results among various types of equipment is not the purpose of this paper.

E. Student Reaction

Whenever students perform experiments on certain topics, one problem is that they often do not know why they are doing the experiments. They also question why results obtained depend on experimental systems.

Individuals may also ask the same questions, later, when they work in the actual field, after graduation.

In order to address on this problem, the experimental course described in this paper is composed of the Simulink for Laboratory and a PLC and C program for an actual plant. This is mainly applicable to a small plant or automation system. The DCS is applicable to a large power plant or chemical process. Before taking this course, both undergraduate and graduate students may not have been interested in experimental courses. However, upon completion, the students realized the value of the courses, and felt quite enthusiastic about the practical knowledge gained.

F. Textbook, Laboratory Manual

There are many kinds of experimental systems and textbooks, all over the world. However, it is difficult for instructors to introduce an experimental system, focusing on the experimental purpose, using only the manual, since there is no a detailed description for experimental equipment before it is introduced into a laboratory. One of the additional problems is that there are sometimes incompatible descriptions between experimental textbook and experimental equipment. Therefore, if instructors decide to introduce an experimental system, with only the manual, the purpose of the usage of experimental equipment might be different from instructor's will, or the purpose of the original experimentation of the course. Through this course, a detailed textbook on the experimental equipment could be prepared.

G. Impact on Industry/Laboratory/Universities

This course could have an impact on both the industrial field and laboratories in universities. The companies that produce the experimental equipment for educational purposes are often small or medium sized. They may not have the capacity to research basic theory or operational principles. In this course, relevant information about the design of experimental equipment could be obtained, and a university could prepare educational problems for experimentation with confidence.

VII. CONCLUSIONS

Multivariable process systems such as power plants, feedwater, the circulation system of chemical plants, ventilation systems in buildings, water purification systems, or wastewater systems consume a great deal of electrical power.

Up to this point, the PID controllers that have been used in these systems have had many problems, including an inability to control fluid systems accurately, because of coupling characteristics among the loops, and many kinds of disturbances. In addition, a great deal of money is required to prepare equipment for these experimental purposes at a time. Hence, many instructors may hesitate to introduce these systems into a laboratory.

This paper introduces an experimental method and an educational course that can effectively incorporate a complicated fluid system into curriculum. Also, this paper proposes a new control method, composed of a fluid system of a multivariable control loop, which applies a NN-Tuning 2-DOF PID controller to experimental equipment. The results could have an impact on the educational method used for experiments. The simulation and experimental results in a parallel process represent a satisfactory response against a disturbance and a change of setpoint.

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