Virtual Air Pressure Tank System for Open and Closed Loop Simulation

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Abstract – **The purpose of this paper is to develop virtual air pressure tank system for open and closed loop simulation. The development of the system is accomplished via G-programming language potentialities of LabVIEW™ version 2011 running on ACER Intel Core™ i5-2430M 2.4GHz with Turbo Boost up to 3.0GHZ, 4GB DDR3 computer with Window7 Home Premium operating system. The system is designed to mimic the air pressure control trainer model SOLTEQ SE121 which installed at the Process Control Laboratory, Faculty of Electrical Engineering, UiTM Shah Alam. The system developed able to offer as a learning tool to help student more understand experimental work in which students able to differentiate between open loop and closed loop experiment as well as determine the process parameters before entering to the actual laboratory.**

Keywords- LabVIEW; Virtual Air Pressure Tank System; Open Loop; Close Loop; Process Parameters

I. INTRODUCTION

Leading a laboratory session has particular challenges and opportunities that differ from those in a standard classroom environment [1-3]. Beside the laboratory procedures and instructions for laboratory works, students need to prepare themselves with related theory before run the experiments. Simulations and related learning aid that can lead to the experimental works is needed in order to prepare the students with ideas and motivations to conduct the experiments [2].

The air pressure control is one of the experiment modules that compulsory for students who enrolled EE230 program. The experiment is performed using the air pressure tank system. However, there was only one air pressure tank system available for the experiments in which a group of 4 students to take turns in carrying out the experiment. Furthermore, the students are unable to retrieve experiment data other than the plot of the pressure response. This contributes to a waste of time and lack of efficient equipment. Therefore, it is an aim to have an alternative way of carrying out experiment.

The objective of this project is to develop virtual air pressure tank system for open and closed loop simulation. The project is focused on the determination of process parameters in an open loop system and the display of the dynamic performance in a closed loop system. The system development is aim to help student more prepared before run the experiment on the actual process plant.

II. AIR PRESSURE CONTROL TRAINER

The Air Pressure Control Trainer installed in Process Control Laboratory, Faculty of Electrical Engineering, Universiti Teknologi Mara (UiTM), Shah Alam is as shown in Figure 1. It has been designed to expose students with hands-on experience on how a pressure loop can be controlled via microprocessor controller.

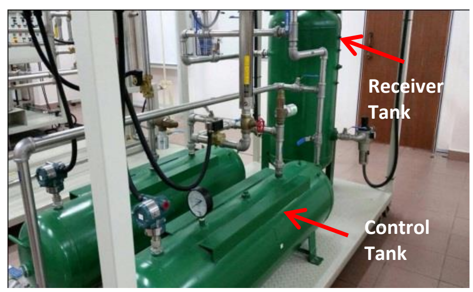

Figure 1: Air Pressure Control Trainer

The SOLTEQ Model: SE 121 Air Pressure Control Trainer is an air process where 6 bar (g) of compressed air is charged into the air receiver tank, V-301. Air from V-301 is passed through the process line into the control tanks, V-302 and V-303. In case of overpressure in the receiver and control tanks, both tanks have been fitted with pressure relief valves PSV-301, PSV-302 and PSV-303 respectively. The process piping is made of industrial pipes. Electrical wiring is in flexible PVC conduit and all instrument cables are screened. The Process Control Trainer is a mobile self-contained unit required only the available 240 VAC/ 50Hz and 6 bar(g) instrument air supply.

Figure 2 shows the piping and instrumentation diagram (P&ID) of the system. The important part of the system is the two identical horizontal pressure control tanks where the measurement and control of the pressure is taken. Each of these tanks can accommodate up to 5 bar air pressure.

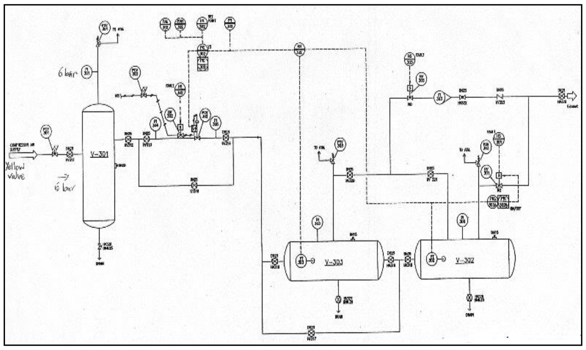

Figure 2: Air Pressure Control Trainer P&ID

The experiments are carried out to evaluate the performance of the proportional–only and PI controllers for air pressure control tank system.

III. LabVIEW™

LabVIEW acronym for Laboratory Virtual Instrument Engineering Workbench is a graphical programming environment that has been developed to facilitate the hardware with the software communication.

LabVIEW program is in contrast to text-based programming languages which it uses dataflow technique. A dataflow paradigm is where the code is not written, but rather drawn or represented graphically similar to a flowchart diagram. LabVIEW program is made up of two components known as front panel and block diagram [4].

A. LabVIEW Front Panel

LabVIEW front panel is the interactive user interface that constructed with different elements such as controllers, indicators, meters, constants and graph plotter. For instance, controllers are knobs, push buttons, dials and other input devices.

B. LabVIEW Block Diagram

LabVIEW block diagram is the graphical source code that defines the functionality of the instrument. In this case, the program execution follows connector wires linking processing nodes together. Unlike most programming languages, LabVIEW compiles code as it is created thereby providing immediate syntactic and semantic feedback and reducing the time required for development and testing [4].

IV. PROCESS MODEL

The understanding to the characteristic of the process to be controlled is essential in order to determine the optimum controller parameters. Normally, the industrial process is represented using first order plus dead time (FOPDT) model as shown in Eqn. (1) [5].

$$Gp(s) = \frac{K_P e^{-Ls}}{Ts+1} \qquad \ldots (1)$$

K_P is the process gain. The term L and T in the equation represent the time delay and process time constant respectively. L is calculated as delay from manipulated variable is issued until when the process variable start to respond.

The determination of the process parameters is as shown in Eqn. (2) and Eqn. (3)

$$K_p = \frac{y_{final} - y_{initial}}{u_{final} - u_o} = \frac{\Delta_y}{\Delta_u} \qquad \ldots (2)$$

$$T = t \; at \left(0.632\Delta_y + t_{initial}\right) \qquad \ldots (3)$$

V. PI CONTROLLER & TUNING

In general, the PI controller performance is depends on the adjustment of the controller parameters known as tuning [6]. The optimum controller parameters adjustment is depend on the process to be controlled and tuning criterion. There are various tuning methods available in the literature [6-9]. One of the most tuning methods is Ziegler-Nichols Reaction-Curve Tuning (ZNRCT) method [10-13].

Using ZNRCT method, the PI controller parameters can be calculated using Eqn. (5) and Eqn. (6).

$$K_C = \frac{0.9}{K_p}\left(\frac{T}{L}\right) \qquad \ldots (5)$$

$$T_i = 3.33L \qquad \ldots (6)$$

VI. METHODOLOGY

In this work, the virtual system is designed in such that the user is allowed to adjust the control parameters and also observed the process response on the interface. The development of the virtual system is divided into two parts namely open loop system and closed loop system.

Open loop system designed is more focused on the determination of process characteristic from experimental data. In this work, the experimental data in excel file format is plotted accordingly and the important process parameters are calculated from the plot. The parameters that describe the characteristic of controlled process are then identified and displayed in a form of transfer function.

Whereas, the closed loop system is designed as a fully automatic control in which its control action is being dependent on the output. In this phase, the optimum value for the controller parameters is selected and the corresponding output response is then displayed on the screen.

VII. RESULTS AND DISCUSSION

A. *Virtual Air Pressure System*

Figure 3 shows the front panel of the developed virtual air pressure system that mimic the actual instrument for continuous process applications whereas Figure 4 shows the programming module for the system.

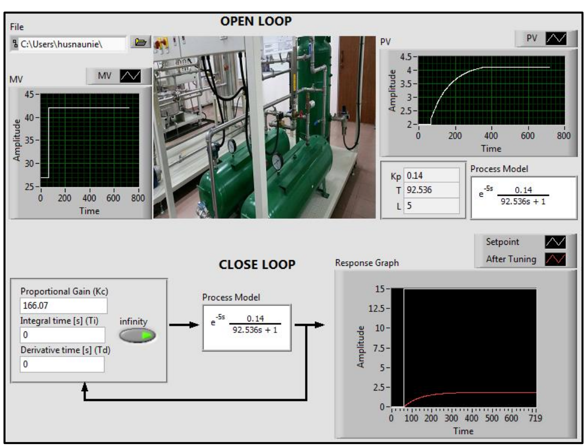

Figure 3: Front panel of virtual air pressure tank system

The controls and data displays for the system are designed so that the observation and control of the system can be done via software environment. These programming modules can be modified at any time by the user according to specific needs.

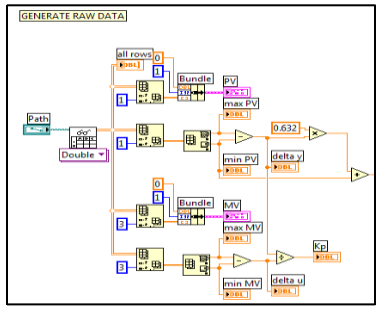

Figure 4: Block diagram of virtual air pressure tank system

B. *Open Loop*

Figure 5 shows the front panel and programming module for open loop air pressure control system. As shown are the process variable (PV) plot and its corresponding important process parameters.

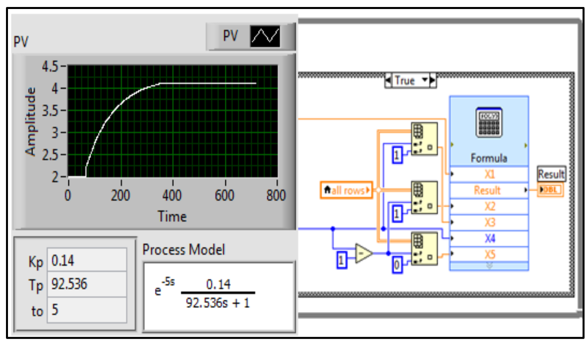

Figure 5: Front panel and programming module for open loop system

The system able to read the experimental data in excels file format and identifying the important parameters of the controlled process. In addition to that, the parameters are then displayed in a form of transfer function. However, the system can only compute first order and FOPDT process model.

C. *Closed Loop*

Figure 6 shows the front panel and programming module for closed loop air pressure control system. As shown, the closed loop interface consists of panel for controller parameters setting, process model and waveform graph display.

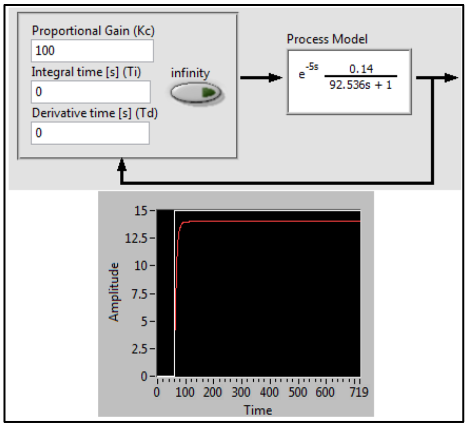

Figure 6: Closed loop system for P-only controller

Figure 7 shows the sample result for air pressure tank system with P-only controller. User need to calculate first the value for Proportional Gain (Kc) and push the infinity button to make the Integral time (Ti) constantly infinity. Enter the value for P gains to the controller parts to gain the response graph.

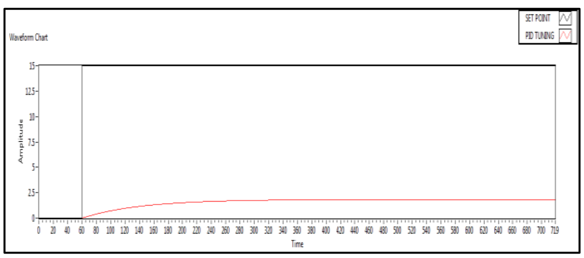
Figure 7: Process response with P-only control

Figure 8 shows the sample result for PI controller. User need to calculate for P and I value using (ZNRCT) method. Enter the value for P and I gains to the controller parts to gain the response graph.

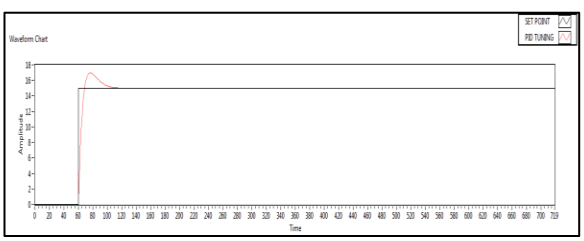
Figure 8: Process response with PI control

VIII. CONCLUSION AND FUTURE DEVELOPMENT

A virtual air pressure tank is successfully developed and tested. The developed user interface, gives the flexibility to observe on graph before and after tuning using ZN method. This system is able to help students prepared well before run the actual experiment in the laboratory.

This system can be extended to underdamped second order system and can also determine the entire dynamic performance criterion such as overshoot, rise time, settling time, and decay ratio.

REFERENCES

[1] Brad A. Myer, “A Brief History of Human-Computer Interaction Technology”, *Interactions* 5, 2, pp. 44-54, March 1998.

[2] M. Hearst, "User Interfaces and Visualization," in *Modern Information Retrieval*, R. Baeza-Yates and B. Ribeiro-Neto, Eds., Harlow, England: ACM Press/Addison-Wesley Longman Publishing Co., 1999, pp. 257-323.

[3] Mohammad A.K. Alia, Mohammad K. Abu Zalata, “A closed-loop temperature control system by utilizing a labview custome-design PID controller,” Faculty of Engineering Technology Al-Balqa’ Applied University Amman, Jordon, ducati.doc.ntu.ac.uk, uksim (2004)

[4] LabVIEW User Manual, April 2003 Edition, National Instruments [Online]. Available: http://www.ni.com/labview

[5] Abdul A.I, Zalizawati A.. “ PID Fundamental Concept and Applications”, Penerbit Press UiTM 2013

[6] D.E. Seborg, T.F. Edgar and D.A. Mellichamp, “Process Dynamic and Control”, *John Wiley & Sons Inc.*, New York, 2nd Ed. 1989.

[7] A. O’Dwyer, “A Summary of PI and PID Controller Tuning Rules for Processes with Time Delay. Part 2: PID Controller Tuning Rules”, *Proc. of PID ’00: IFAC Workshop on Digital Control*, pp. 242-247, 2000.

[8] K. Ang, G. Chong and Y. Li, “PID Control System Analysis, Design and Technology”, *IEEE Trans. Control System Technology*, vol. 13, pp. 559-576, 2005.

[9] Zhuang, M.; Atherton, D.P.; , "Automatic tuning of optimum PID controllers," *Control Theory and Applications, IEE Proceedings D* , vol.140, no.3, pp. 216- 224, May 1993

[10] Hang, C.C.; Astrom, K.J.; Ho, W.K.; , "Refinements of the Ziegler-Nichols tuning formula," *Control Theory and Applications, IEE Proceedings D* , vol.138, no.2, pp.111-118, Mar 1991.

[11] James B, Ajay B, Jamila Grant, Wen C.L, “ PID Tuning Via Classical Methods”, October 2006

[12] Control”, *John Wiley & Sons Inc.*, New York, 2nd Ed. 1989.

[13] C. Knospe, "PID Control," *IEEE Control Systems Magazine*, vol. 26, pp. 30-31, Feb 2006.