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A NEW METHOD FOR LOW COST GROUP-BASED EXPERIMENTS IN PRESSURE CONTROL SYSTEMS

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ABSTRACT

The cost of control system for education is getting higher and is placing extra load on the universities budgets. It is formidable to see more than five people running an experiment. The number of people joining in one experiment should be as low as possible. However, this might imply that the university/college must either have funds for buying four or five replicates of the same device or appoint more than one engineer to run the experiment. A feasible alternative is suggested in this work in which the students run the experiment through computers communicating with a PLC controlled test rig through a wireless network. A suitable number of students/computer is selected by the university. The wireless network control is for two main purposes: firstly to accept entries for various control parameters from the students and secondly to display the pressure response for them. All computers show the same display. The system includes: calibration for the sensors, the actuator, manual control part (open loop control) and automatic control (closed loop control part).

Keywords: Educational control systems, group based control, open loop control, closed loop control.

INTRODUCTION

The challenge with overburdened educational system is to give engineering students a grasps of real physical systems. It is costly to replicate practical realistic training systems. Enough student-device interaction must be given for good learning experience. Theoretical discussion may be greatly enhanced with proper practical exposure which can lead to more student motivation for learning. However an integrated device/low number of students may not be infeasible. Thus one solution was to reduce the cost of training kits. Design of low cost kits in control is a necessity. There has been a design of low cost Maglev Kit (Gamboa-Revilla, 2010), low cost microcontroller of servomotors (Rubbai, 2000), low cost robots (Ceccarelli, 2003) etc. However, reducing the cost of such systems might imply reduced functionality or downscaling which might make the resembled system different to the one under experimentation. Another solution is the "low-cost take-home" kits [4-9 (Scoot, 2000; Durfee *et al*., 2004; Wang *et al*., 2004; Palm, 2010; Kits, 2009). For engineering students in introductory system dynamics and control courses who need to gain intuitive feel for physical systems, the distributed laboratory may give a hands-on experience that uses inexpensive, custom hardware and software kits which is brought home by each student and tackled on a self-paced schedule (Durfee *et al*., 2004). The "take home" kit is a growing phenomena. It increases student exposure. However, it might be easily damaged through the use of inexperienced user. The take home kit are simplified versions of industrial controllers and may not resemble realistic experience.

This work suggested a new technique to give supervised training with equal student exposure on a laboratory kit that resembles real life industrial based pressure control system using only one test rig. This is done through distributed monitoring computer stations communicating wireless with a PLC that controls the test rig. The system is formed of several parts calibration, manual control and automatic PID control systems.

MATERIALS AND METHODS

The test rig

This work is devoted to the control of the Pressure Process Station, Model 3501. The basic components of the 3501 system are: two 7.5-l (2-gal US) air tanks, an air pressure regulator, an exhaust assembly, a pneumatically operated flow control valve, needle valves at the tanks and exhaust assembly connections, a kPa/psi-graduated pressure gauge, an electronic pressure transmitter, and a current-to-pressure (I/P) converter, a flowmeter and an orifice assembly. The main system controller is the proportional, integral, and derivative (PID) control by

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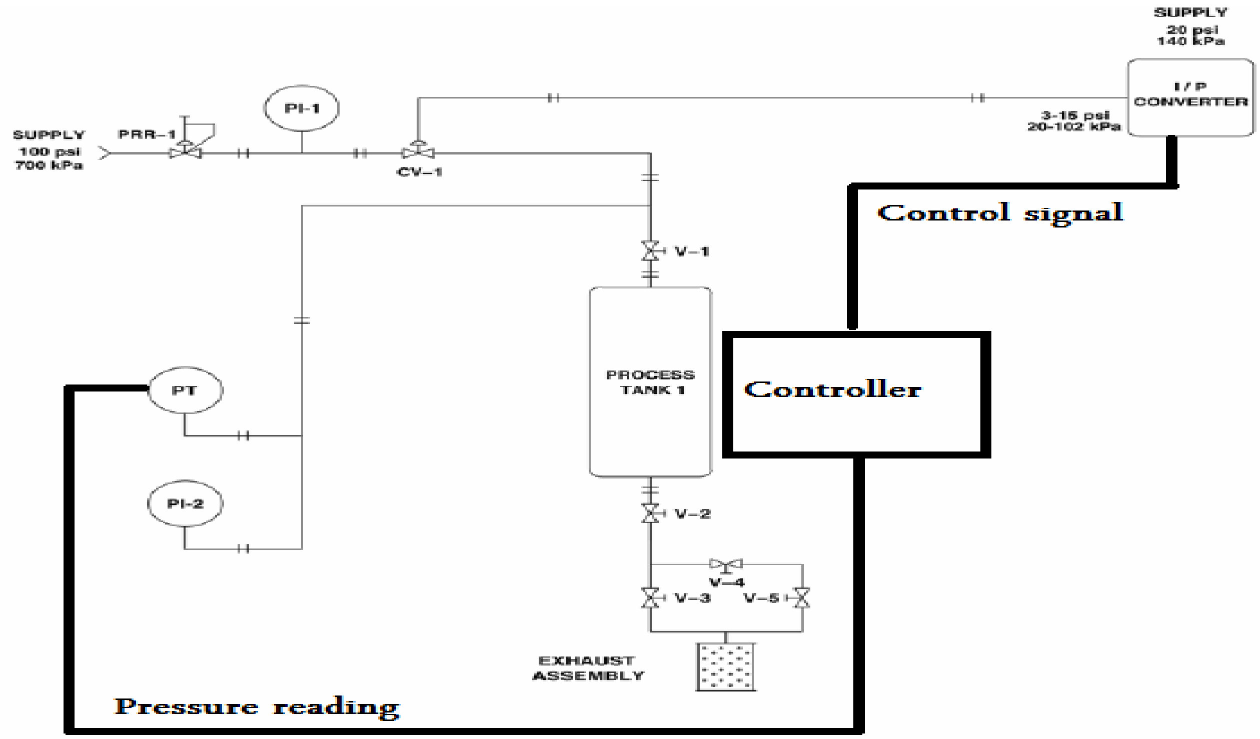

Fig. 1. A schematic of the 3502 pressure controller and the 3501 test rig .

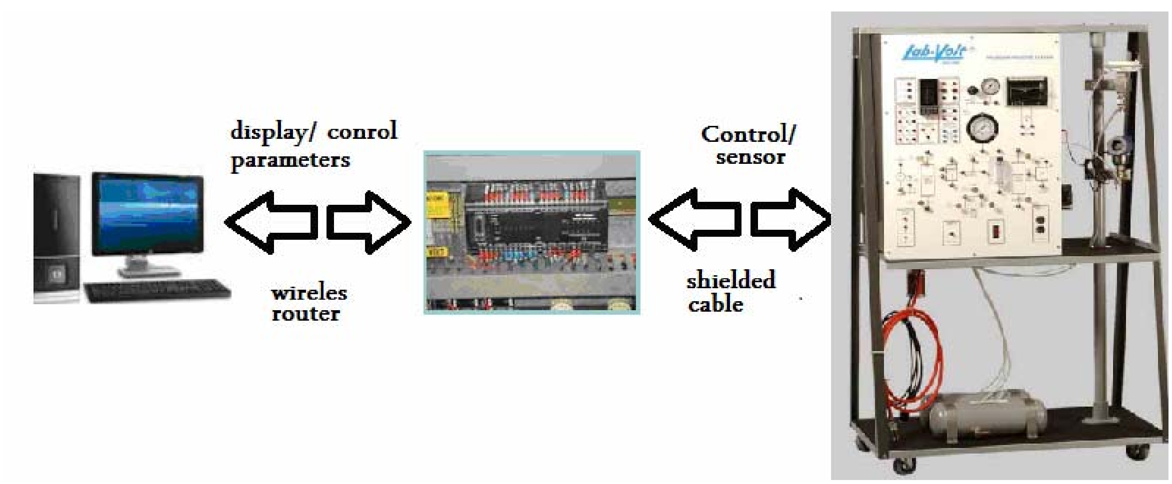

Fig. 2. Illustration of the new control system data transfer.

throttling the air inflow to these tanks using the pneumatically operated flow control valve with a 4-20 mA signal (Labvolt, 2015). Loading is done through the exhaust assembly. Also we can introduce a disturbance through the needle valves or by vary the circuit restriction to air flow that can modify the process response characteristic (see Fig. 1).

The controller system

The proposed control system is composed of a Personal Computer (PC) as a human machine interface with students, PLC as the PID controller and the pressure test rig (see Fig. 2).

DISCUSSION

The software

The software designed is interactive that accepts students inputs and displays the pressure readings. The software is designed to run the experiments in stages (Fig. 4) where the students are guided step by step. The sensor transducer is calibrated by the students in the PT calibration stage (Fig. 5). In this stage the students reads the pressure gauge and records it against sensor readings. The second stage is I/P calibration figure 6. In this stage the system changes the input current while automatically recording the D/P sensor. The students just give a check

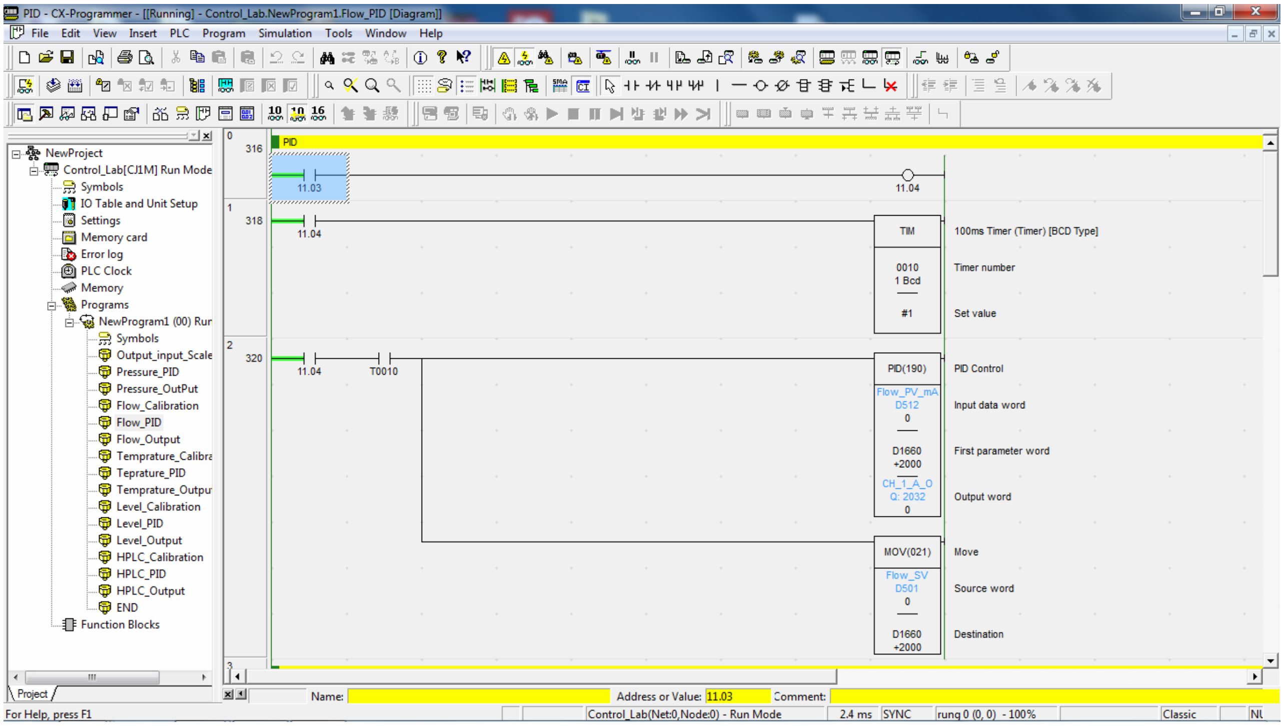

Fig. 3. A snapshot of the PLC ladder logic programming for the PID in the CX-one software.

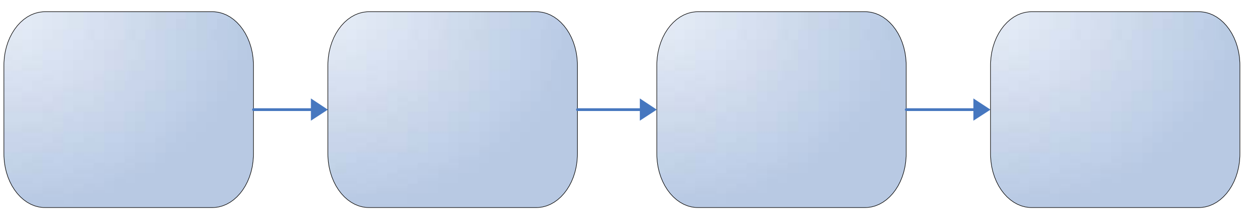

Fig. 4. Stages for the software.

input that the pressure readings are recorded correctly. In manual open loop control stage figure 7, the students enter a current setting for the I/P and the software shows the pressure response. Now the instructor introduces a load disturbance though modifying one of the exhaust valves to illustrate that the open loop system is highly sensitive to disturbances. In the automatic PID stage, the students start by setting only the K_p value which results in high steady state error values in low K_p value (Fig. 8), which can be reduced by using high K_p value but we are faced with Oscillations and even instability (Fig. 9). The students can see this instability at the pressure gage reading and hear it through the I/P going high and low. Finally introducing K_i value (Fig. 10) can reduce the error without increasing K_p. The instructor then introduces mechanical load changes through one of the exhaust valves to show that system goes back to the set value unlike the open loop system whose controlled output is changed permanently.

CONCLUSION

In this work a PLC based controller pressure control kits with wireless connection to PC stations is introduced. The system leads the experiments in stages: Calibration, open loop and closed loop control. The system demonstrates the concept of open loop, closed loop, instability and PID control successfully with high student exposure.

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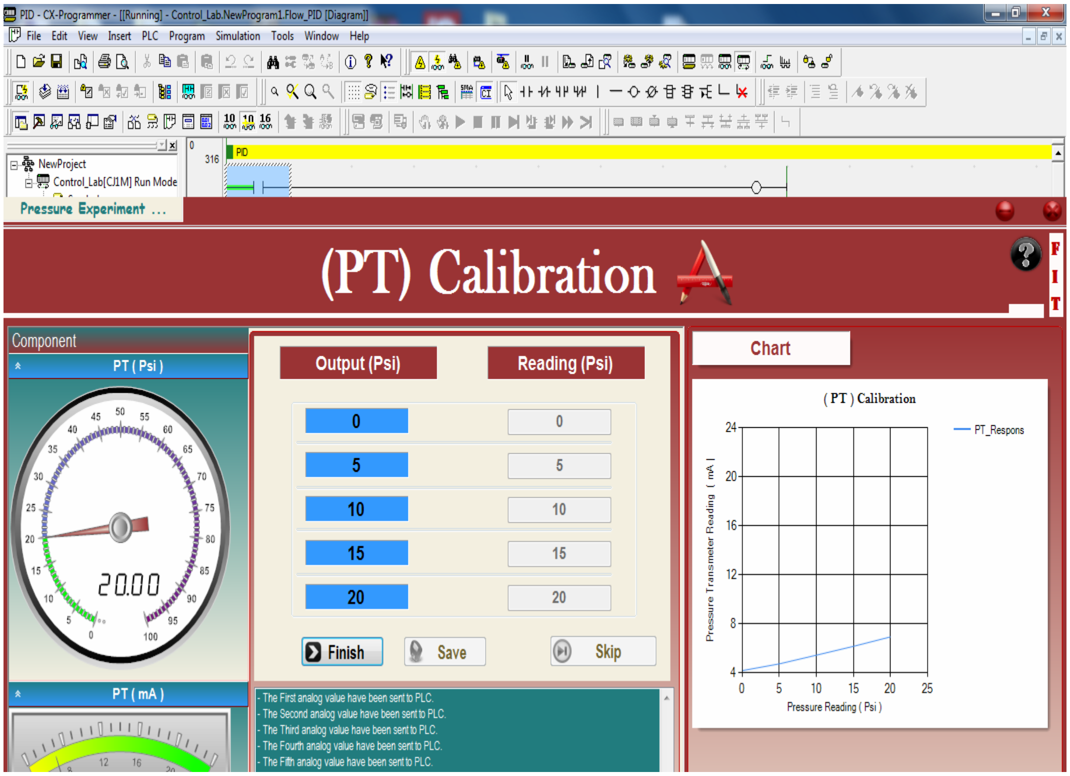

Fig. 5. PT calibration stage.

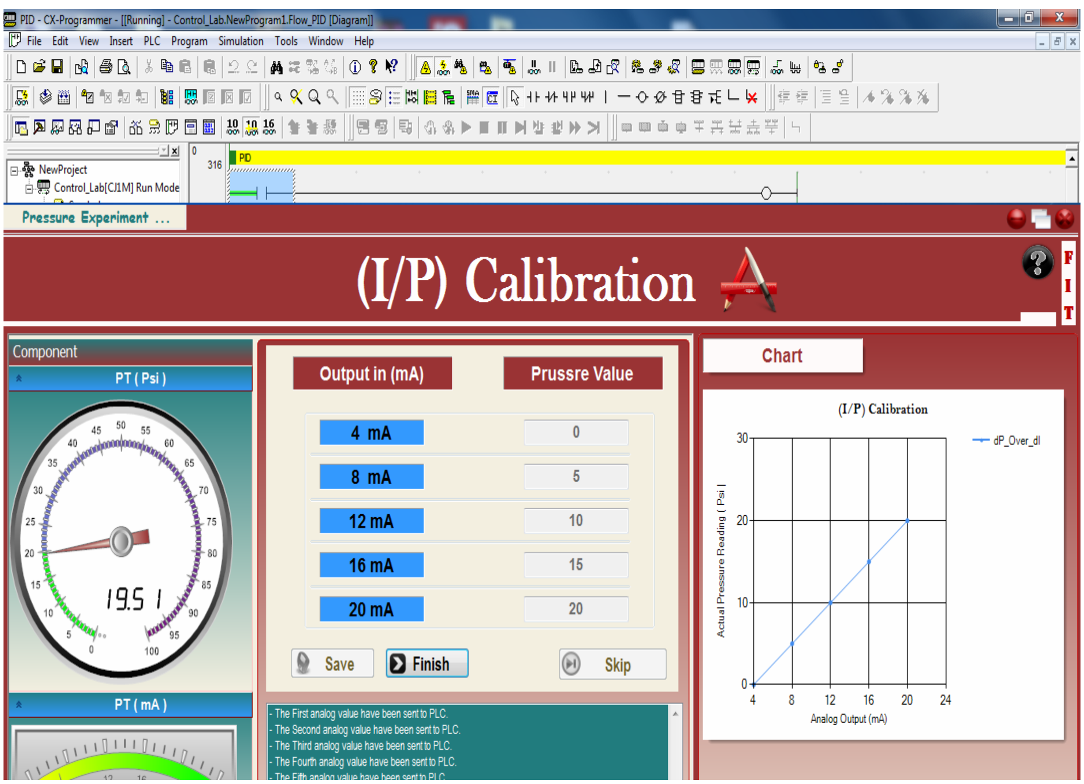

Fig. 6. I/P calibration stage.

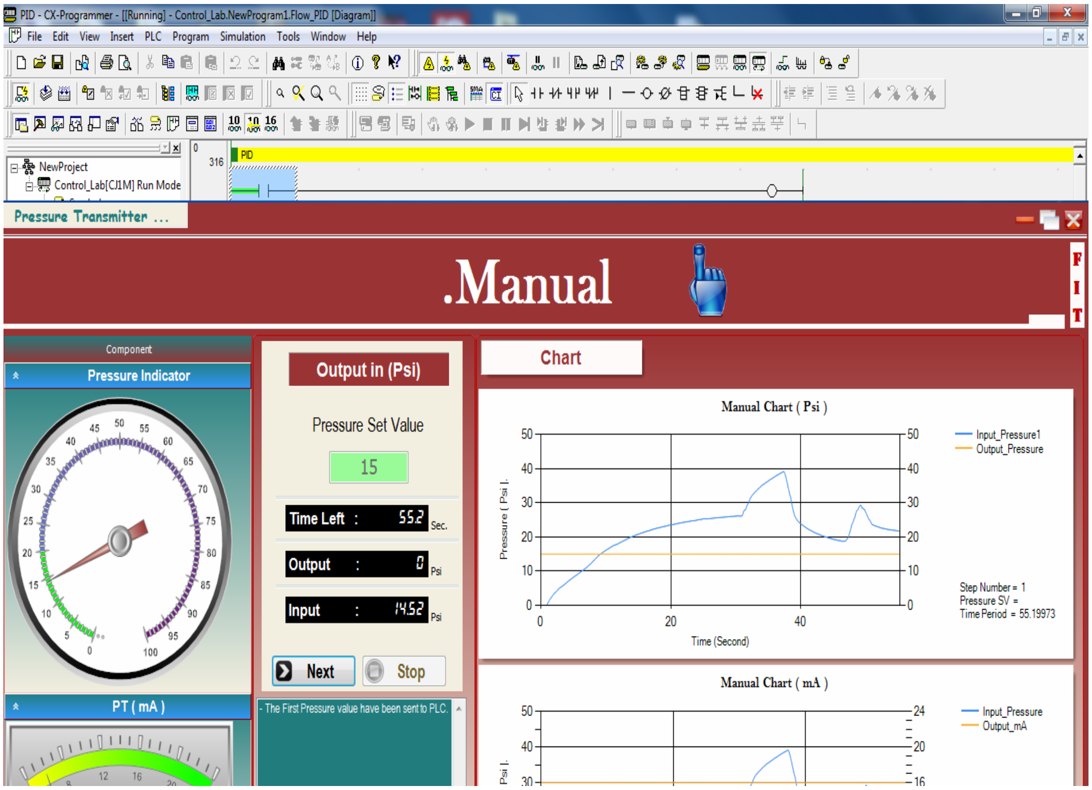

Fig. 7. Manual control stage with high and low load disturbance introduction.

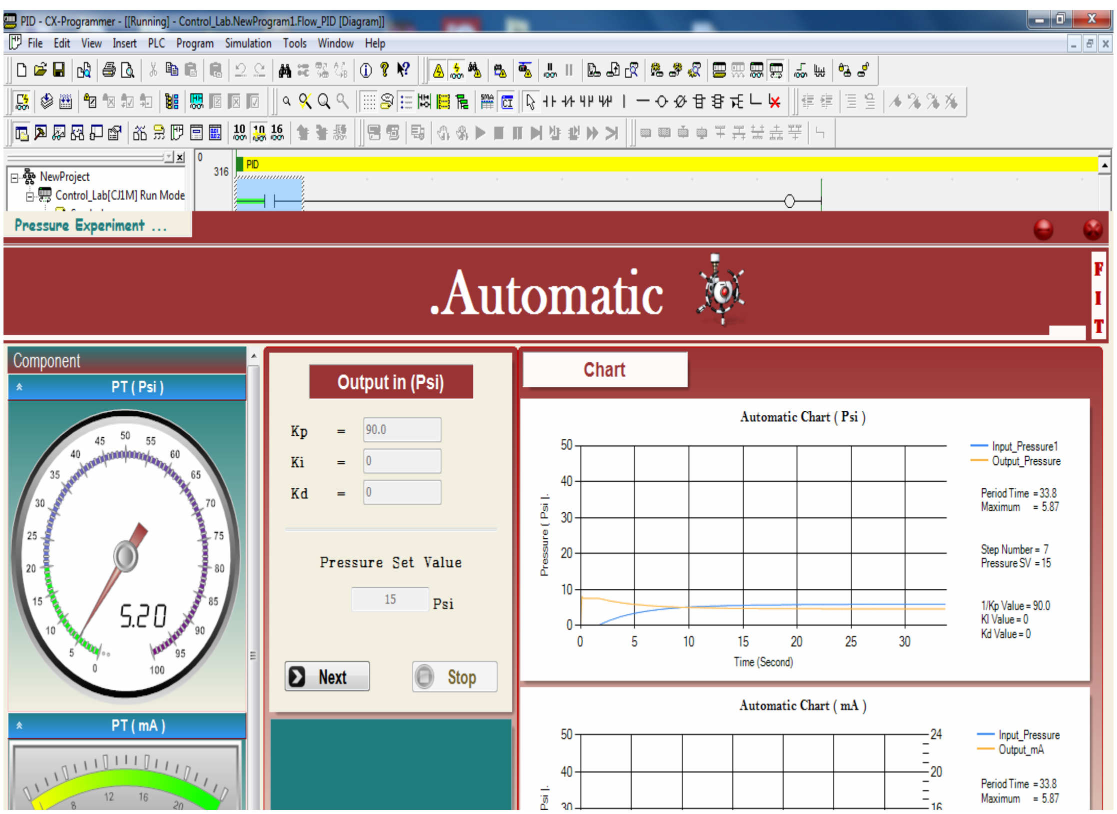

Fig. 8. Automatic closed loop control with kp=90, Ki=0 . Steady state error is noticed.

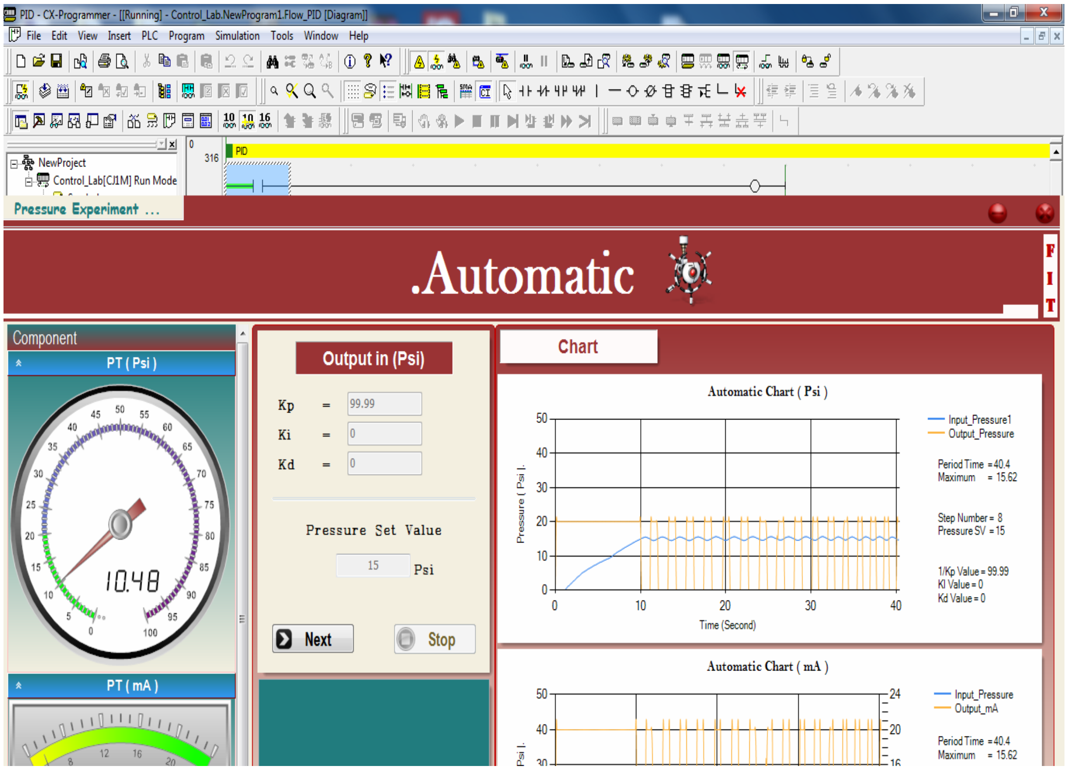

Fig. 9. Automatic closed loop control with kp=99.99, Ki=0 . Steady state error reduced but oscillation are shown.

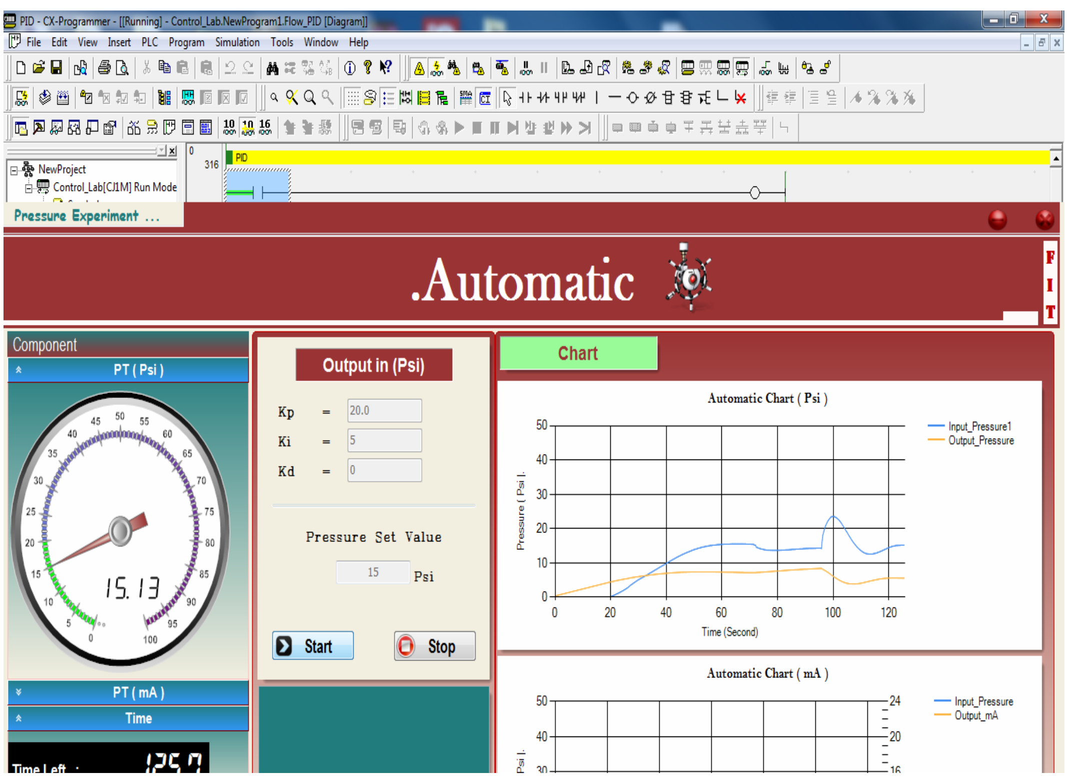

Fig. 10. Automatic closed loop control with K_p=20, K_i=5 . Steady state error is eliminated. Deliberate introduction of load disturbance and the system goes back to the set value.

REFERENCES

Ceccarelli, M. 2003. Low-Cost Robots for Research and Teaching Activities. IEEE Robotics and Automation Magazine. 10(3) :37-45.

Durfee, W., Li, P. and Waletzko, D. 2004. Take-home lab kits for system dynamics and controls courses. In: Proceedings of the 2004 American Control Conference, Boston, MA, USA. 1319-1322.

Gamboa-Revilla, J. 2010. Maglev Kit: A Servo/ Regulatory Configuration For Low-Cost Educational Laboratories", Lecture Notes in Engineering and Computer Science . 2187(1):955-959.

Jouaneh, M. and Palm,W. 2009. System Dynamics Take-Home Laboratory Kits. In: Proceedings of the 2009 ASEE Annual Conference, Austin, TX, USA. 1-8.

Labvolt. 2015. http://www1.labvolt.com/publications/ Datasheets/Current2/ dsa3500.pdf

Palm, W. 2010. System Dynamics. (2nd edi.). McGraw-Hill, New York, USA.

Rubbai, A. 2000. Training undergraduate students in sensing and control technologies. International Journal of Engineering Education. 16(6):534-543.

Scott, T. 2000. Two “take home” experiments in fluid mechanics. In: Proceedings of the 2000 ASEE Annual Conference and Exposition, St. Louis, MO. 6451-6458.

Wang, E., Lacombe, J. and Rogers, C. 2004. Using LEGO bricks to conduct engineering experiments. In: Proceedings of the 2004 ASEE Annual Conference and Exposition, Salt Lake City, UT. 15085-15102.

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