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Process Control Virtual Laboratory: Temperature Control Based on LabVIEW for Convection Heat Transfer

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Abstract. The process control virtual laboratory is created by using LabVIEW for demonstrating process control via manipulating a simulated model of a physical process. In this study, a system of convection heat transfer in a rectangular duct is set up and connected with a data acquisition card and a computer serving for an advanced virtual laboratory aimed at supporting teaching and learning in Instrumentation and Control Engineering courses at Pathumwan Institute of Technology. The use of the virtual laboratory facilitates the ongoing evolution of the teaching method from a traditional didactic lecture and laboratory course to a more student-centered approach. The LabVIEW application is used to conduct several tasks including user interface design, publishing and sharing measured data, instrument control and remote access to a system in the Process Control Laboratory. Using LabVIEW software, students can familiarize the basic skills necessary to use equipment and software because the control systems in many industrial processes can be implemented on a computer which runs on LabVIEW.

Introduction

Process control laboratory is crucial components of control engineering education. In the present and future control learning, the information technology is moving towards effective and efficient application in control education and the time has arrived for virtual and remote laboratories through simulations [1]. The appeal of virtual and remote laboratory tools is mostly due to the increasing requirement for active learning and flexible education, and for the appeal of implementing techniques of learning via discovery [2]. Active learning seeks to give students with opportunities to better integrate and strengthen knowledge presented in the classroom, as well as to achieve the practical know-how that is such an essential component in engineering education [2]. The use of computer based techniques to interface the students with the physical world, with proper front end design to provide enlarging sophistication and flexibility is one way for reducing the use of expensive laboratory hardware and infrastructure. Virtual laboratory is a virtual experiment environment in which users can operate a series of graphical units, each one representing an experiment object, to perform remote virtual or genuine experiments via the internet by local operation of the mouse or keyboard [3]. In addition, virtual laboratory makes it possible for students to do experiments flexibility that enhances the student's enthusiasm for learning and improves the interaction between teaching and learning as well.

As automatic control ideas, concepts and methods are actually rich in visual contents represented intuitive and geometrically, these visual contents can be used for presenting tasks and handling concepts and methods, and manipulated for solving problems [1]. Although there are a number of interactive computer-delivered simulation, control and scientific visualization software solution in the market, however, for the suitable software choice, the main criteria contemplated for selecting application software to develop virtual instrumentation applied in control engineering education are modularity, multi-platform portability, compatibility with existing code, compatibility with hardware, extendable libraries, advanced debugging features, executables, add-on packages, performance, intuitive Graphical User Interface (GUI) and multimedia capabilities [4]. Due to its overall versatility as a control engineering tool, the commercial LabVIEW software is chosen in most of the engineering problems. It is a graphical programming language that allows engineers and scientists to build their own virtual instrument. It is flexible, modular and economical and it also meets most of the software selection criteria. Furthermore, LabVIEW has module and toolkit for control engineering education, such as control design and simulation module, PID & Fuzzy logic toolkit, real-time module and other modules and toolkits for engineering education. LabVIEW software either allows a user to interact with an experimental set-up located in another geographical location such as a remote laboratory or uses numerical simulation tools to emulate the behavior of an experimental system as a virtual laboratory.

So far, there are many applications of LabVIEW to create the virtual and remote laboratories for engineering teaching and practice [2-8]. Accordingly, the process control virtual laboratory based on LabVIEW becomes an optional way being modern experimental teaching being a student-centered methodology. The main purpose of this complete work is to design a new alternative educational environment for Instrumentation and Control Engineering program at Pathumwan Institute of Technology. This will help to design a remotely accessible the Process Control Laboratory being the most real virtual application while controlling real instruments remotely that will support the student's works from another computer in the distant room located on the Institute by using only one real experimental rig via LabVIEW software. Thus, it can conveniently and efficiently overcome the problem of deficiency of training resources. Generally, the four main experiments of process control include level, pressure, temperature and flow rate control. Currently, the temperature control experiment is firstly developed as the process control virtual laboratory for the experimental teaching and learning in the Process Control Laboratory course. A system of convection heat transfer in a rectangular duct is selected to perform for learning of the temperature control. In this study, the first part of the experiment set-up associated with a data acquisition (DAQ) card and a computer for the development of process control virtual laboratory has been conducted to generate user interfaces on the computer by using LabVIEW.

Process Description: Convection Heat Transfer in Rectangular Duct

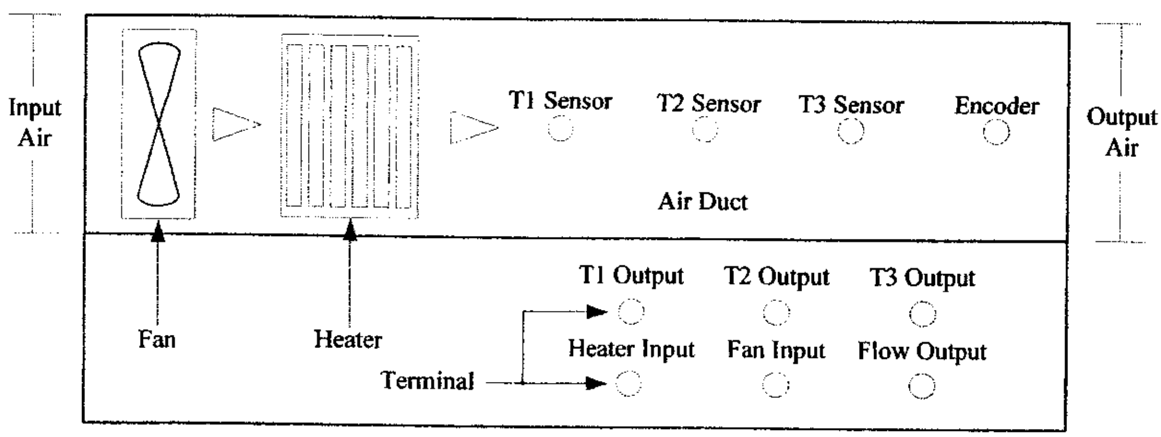

Figure 1 Model of convection heat transfer in rectangular duct.

Fig. 1 demonstrates the model of convection heat transfer in rectangular duct. The atmospheric air forced by electrical fan flows across a staggered tube bank heater to generate hot air in which the heat flow based on internal forced convection heat transfer was presented. An electrically heated process block is mounted in the air flow path such that it reaches thermal equilibrium by balancing the heat gained through the energy supplied to it via the heater tube bank and the heat lost through convection and conduction. Control of thermal process with two inputs and one output (TISO) was demonstrated that multivariable system can be controlled by multivariable controller. In this process, temperature control can be achieved either by varying the heat energy input to the system by regulating electrical power to the heater coil, or varying the heat transfer rate by regulating the air flowrate.

Three RTDs (resistance temperature detectors) are used to measure the actual temperature in the three positions of rectangular duct (T1, T2 and T3) as shown in Fig.1. The electrical fan (EBM-PAPST, 8414N/2GH) can adjust the input signal in the range of 0 to +5 VDC to provide variable air velocity between 1.20 and 1.57 m/s corresponding to the air flowrate from 0.871 to 1.139 m^3/min. The heater supplied with the input signal in the range of 0 to +5 VDC can be controlled the power to the heater at the maximum temperature about 102.8 °C. The output terminal can be used to send the signal and then monitor the temperature of three positions in rectangular duct and the air velocity via LabVIEW.

Process Control Virtual Laboratory

The process control virtual laboratory is developed by using LabVIEW to assist in teaching and learning of control system concepts. The experimental apparatuses are composed of a test rig of thermal process of convection heat transfer in rectangular duct connected with a DAQ card and a computer as depicted in Fig. 2. For virtual and remote laboratory, computers are ubiquitous to integrate part of every engineer's toolbox used to do computations, data collection and reduction, simulations and data acquisition, and to share information via the Internet. Using computers routinely is a reasonably recent event, particularly in the use of simulation in the laboratory that can result in significant financial saving by reducing the time a student or team needs on real and for expensive laboratory equipment, thereby reducing the number of laboratory station required [9].

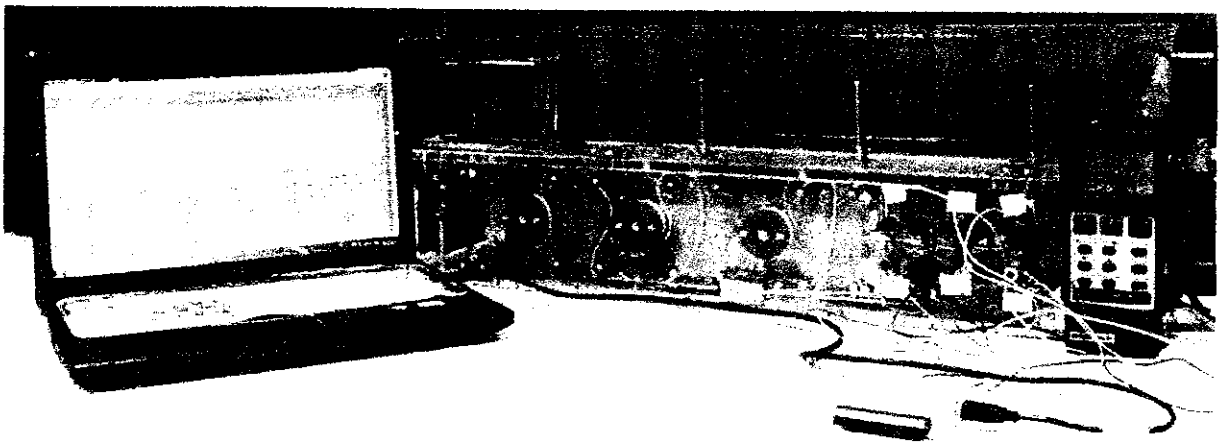

Figure 2 Experimental rig of temperature control for convection heat transfer in rectangular duct.

In the process control laboratory, from the technical point of view, the Instrumentation and Control Engineering courses deal with physical quantities such as temperature, pressure, flowrate and level. A computer equipped with the appropriate interface circuits, DAQ systems and software, can provide a visual aspect to these quantities, can process the required data [4] and can be made available to the remote area user via Internet or Intranet link. However, the future goal of the entire work will be focused on the virtual laboratory based on the web server in LabVIEW that the local area user can be linked with the remote area user via the Intranet link in which experiments can be delivered remotely without having manifold copies of the experimental set-up. In the virtual simulation experiments, the web server is used to share simulation software without instrument hardware but in the ensuing real-time measurement it is connected with experimental instruments through the DAQ card to accomplish data transmission between clients and remote instruments. In this study, the user interfaces on the computer by using LabVIEW connected with the experimental rig was firstly developed.

In this control system design, a proportional-integral-derivative (PID) controller is used to maintain the measured temperature of hot air according to the set point and the PID controller including lead-lag and PID plus lead-lag is programmed using LabVIEW. The block diagram of a control system and the block diagram of LabVIEW are illustrated in Figs. 3 and 4, respectively. The window of block diagram of LabVIEW for the TISO temperature control consists of three parts including the sending and receiving signals associated with the DAQ card (National Instruments USB-6008), the temperature control loop and the air flowrate control loop.

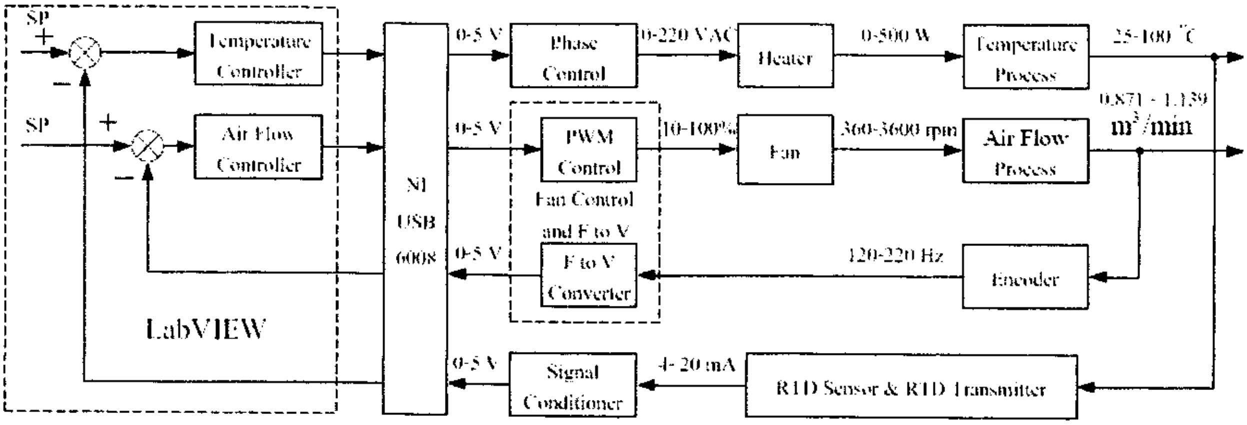

Figure 3 Block diagram of a control system.

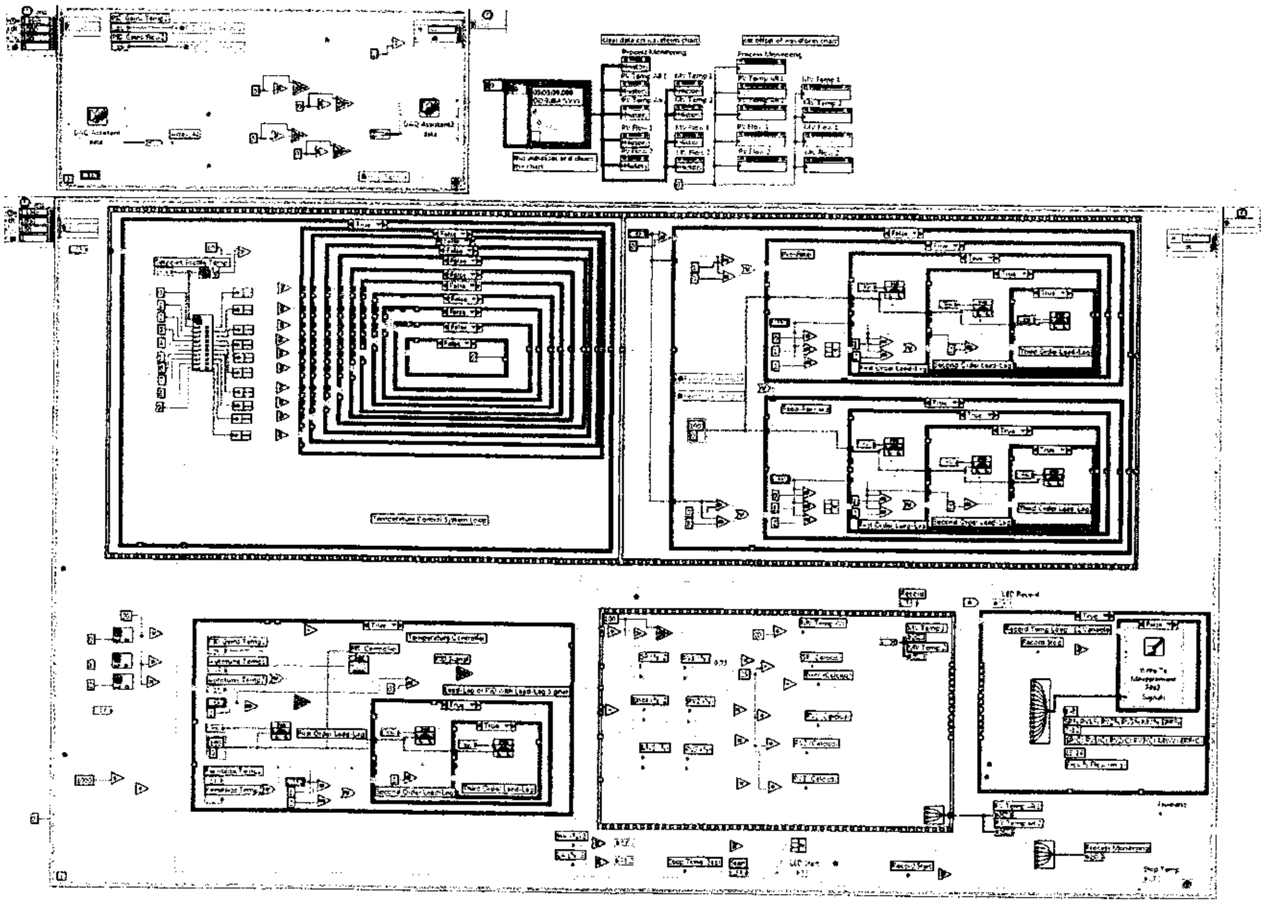

Figure 4 Block diagram of LabVIEW.

The examples of LabVIEW interface are shown in Figs. 5 and 6. Fig. 5 shows the front panel of process monitoring. This window is used to monitor the temperature and air velocity control system response and control signal of both control loops. The real-time measurement can be also presented in this user interface. For the process safety, the alarm for limitation of high and low value is also set up. A result of the response of temperature control system can be demonstrated by LabVIEW as shown in Fig. 6.

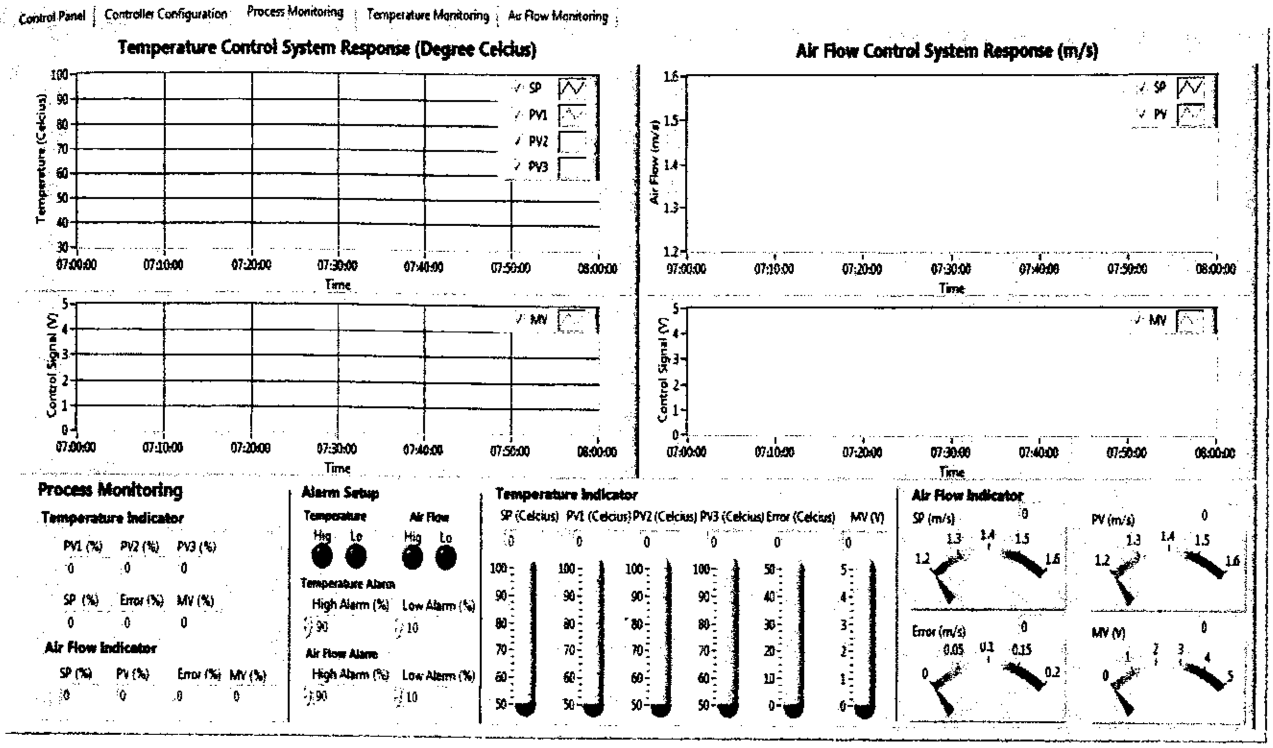

Figure 5 Front panel for process monitoring.

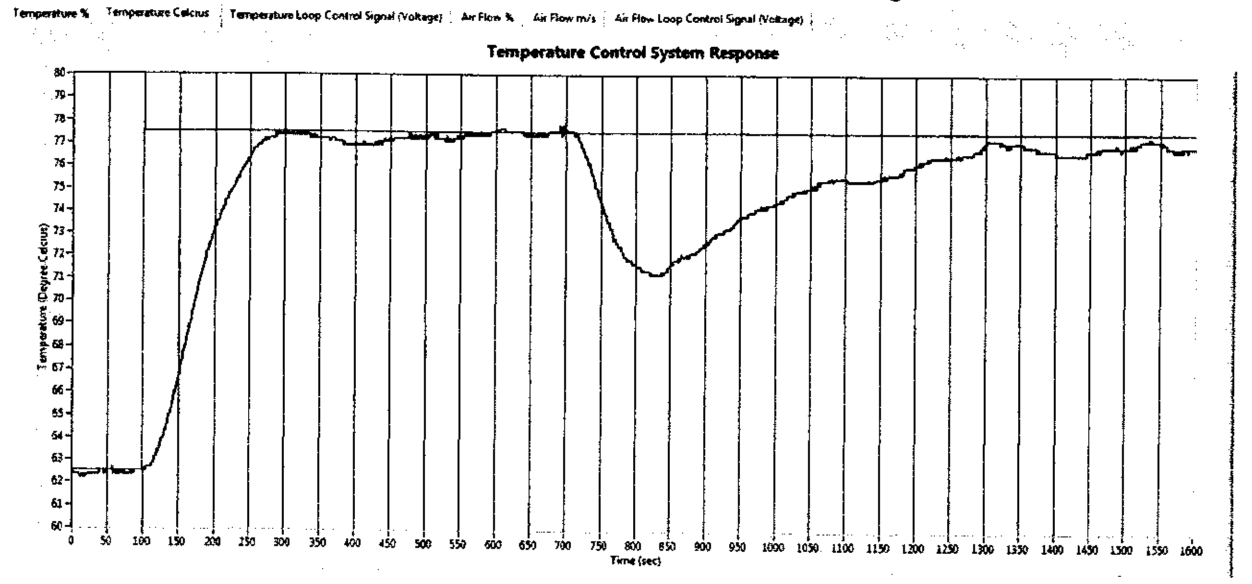

Figure 6 Temperature control system response.

Conclusion and Future Work

In this study, the first part of the experiment set-up connected with a DAQ card and a computer for the process control virtual laboratory has been firstly developed in order to support the laboratory studies of students in the Instrumentation and Control Engineering course at Pathumwan Institute of Technology. Applying the LabVIEW, the student can control the experimental instrument via GUI for process monitoring. It is possible to monitor the changes in the output parameters by changing input parameters of the experiments that show in the front panel by using the PC-controlled instruments and LabVIEW software. Using these equipment and software, students can attain their experience to learn by the modern technology in the process control. Students have deeper understanding of the instrumentation and control engineering principles and their applications. Students can familiarize the fundamental skills necessary to use the equipment and LabVIEW software widely used in many industrial processes. LabVIEW seems the easiest on among the other solutions and it is easy to learn and use for instructors and also students.

In the future work, the virtual laboratory can be developed that students can remotely access to control the experimental instrument via the intranet link at the Institute campus. It can be considered that the difficulty occurring in the applications such as time limitations and group study may be solved at certain level.

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