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Development of a Basic Electro-pneumatic Control Trainer

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Abstract – A basic electro-pneumatic control trainer provides the students' learning experience and appreciation of the subject and course and for the professors' demonstrations and evaluation of students' performance during laboratory time. This study utilized a developmental type of research. The trainer board was a 24 inches by 24 inches by ¾ inch marine plywood. It was cost-effective, space-efficient and portable. It contained circuit breaker, plurality of din rails, plurality of terminal blocks, plurality of relays and relay holders, plurality of normality open and closed push buttons, plurality of utility box, plurality of base plates, plurality of 24VDC (Volt-Direct Current) 3/2 way solenoid valves, plurality of 24VDC indicator lights, tubes duct, plurality of double-acting cylinders, plurality of clamps, and plurality of 24VDC proximity sensors. All the devices were totally exposed for easy installation and familiarization. The plurality of input and output devices terminals were pre-wired into the terminal blocks for faster installation and cost-effective for trainers' maintenance purposes. It was equipped with a low current circuit breaker to facilitate safe operations and eliminate damages to all the devices considering the hard to find and the high cost of the electro-pneumatic control components. It was cable of handling an industrial-like electro-pneumatic control wiring installation, troubleshooting, and commissioning. The basic electro-pneumatic control trainer utilized 24VDC as a power supply for the electrical circuit and a 60psi (pounds per square inch) compressed air for pneumatic control as air supply and supported with the instructional module in basic electro-pneumatics. Demonstration, interview and consultation with the faculty members of the College of Technology, Pangasinan State University – Lingayen Campus teaching BIT major in Electrical, Electronics and Mechanical Technology, the said utility model can perform all the activities listed in the instructional module in basic electro-pneumatics which were also parallel to the real world industry of automation. A basic electro-pneumatic control trainer was granted an Industrial Design (ID) patent by the Intellectual Property Office of the Philippines while still waiting for subsequent formality examination report as a pending application for a Utility Model (UM) patent by the same office.

Keywords: *Electro-pneumatic control, Trainer, Pangasinan State University, Industrial design, Utility model, Intellectual Property Office.*

INTRODUCTION

In many fields of industrial automation, electro-pneumatics were now widely used. Electro-pneumatics were also extensively used in manufacturing, assembly and packaging systems. Relays have been integrated into electro-pneumatic control systems to satisfy the increasing call for more flexible automation. There are three (3) significant steps are engaged in electro-pneumatic control; First, signal input devices–these are generating signals such as switches and contactors, as well as different kinds of touch proximity sensors. Second, signal processing– this is the use of relays and contactors combination. Third, signal outputs– these are the outputs that are acquired after processing for solenoid activation and indicator lights. Electro-pneumatic control comprises of running pneumatic power systems for electrical control. Solenoid valves were used as an electrical and pneumatic system interface. Devices such as sensors were utilized as feedback components. Electro-pneumatic control incorporates pneumatic and electrical systems and was used more commonly in industrial and manufacturing businesses in particular for big applications [1]. The signal medium was used in electro-pneumatics as the source of the electrical signal Direct Current (DC). Operating voltage is frequently used at 24 Volts (V). The working medium is compressed and filtered air which is being measured by pounds per square inch (psi). Solenoid actuation activates the ultimate control valve. The valve reset is either by spring (Single Solenoid) or using different solenoid (Double Solenoid Valve). More often, the pilot-assisted solenoid actuation achieves the valve actuation/reset to decrease the valve size and valued price [2]. Electro-pneumatic system control is carried out either using a combination of relays and contactors. A relay is used on a regular basis to convert input signals from sensors and switches to a range of output signals (normally closed or normally open). Signal transmission can be done easily by relays and contactors combination. Eventually, the output signals are transmitted to the solenoids which trigger the final control valve which controls the motion of various cylinders. The greatest advantage of electro-pneumatics is the application of very effective proximity sensor regulation of different types. [3].

The Pangasinan State University – Lingayen Campus, particularly the College of Technology offers the course entitled Bachelor of Industrial Technology (BIT) with the nine (9) major field of specialization of which three (3) of the major programs have an elective subject of Basic Electro-pneumatics, and these are Electrical Technology, Electronics Technology, and Mechanical Technology. Ever since, the mode of delivering instruction in this subject, the basic electro-pneumatics, was purely lectured in nature considering the fact that this subject has a laboratory unit component. As a result, students who took up this elective subject can visualize the electro-pneumatic applications through internet videos and later, on their seminar and field trips in the different industrial and manufacturing companies.

In an effort to increase the quality of learning outcomes of the students of BIT majoring in Electrical Technology, Electronics Technology and Mechanical Technology, the maker of this utility model seek learning innovation which focused on the design and development of a basic electro-pneumatic control trainer which can be utilized for student practicum during laboratory time.

This research output, a utility model, was compact in design, very light and portable, which can be transferred from one classroom to another. This utility model also can be used for professors' demonstration and for students' laboratory activities performance and evaluation. It also reduced the time spent and problems associated with performing the activities repeatedly. With the use of this utility model, students were able to understand and even learn more by way of actually performing such tasks or activities in regards to basic electro-pneumatics.

LITERATURE REVIEW

In many fields industrial automation, Electro pneumatics are used successfully. Electro-pneumatic control systems power the manufacturing, assembly and packaging process worldwide. In addition to technological advances, the change in requirements has had a significant impact on the appearance of controls. The relay has been gradually replaced by the programmable logic controller in the signal control segment in order to meet the increasing demand for more flexibility. To meet the needs of modern industrial practice, modern electro-pneumatic controls often implement new ideas in the power section. The valve terminal, bus network, and proportional pneumatics are examples of this [4].

Designing and developing a low-cost electro-pneumatic automation trainer kit to be used as an instructional tool in Caraga State University's teaching industrial control in engineering and electrical courses of could be a very feasible equipment to be used in the industrial control laboratory courses as it serves as a mock-up device to simulate the students' actual work. Because of the very expensive laboratory equipment, low-cost electro-pneumatic automation trainer kit has been used to address the problem of inadequate training facilities in SUCs, particularly in industrial control courses. In these classes, the low-cost electro-pneumatic automation trainer kit provides

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quality training in the industrial control laboratory courses without the use of capital-intensive and commercially available equipment. In many areas of low-cost automation, electro-pneumatics are widely used. Electro-pneumatic system control is done either using the relays and contactors combination. Low-cost electro-pneumatic automation trainer kit provided Caraga State University with range of benefits and advantages in successful student training. It also benefits the administrator and instructors in making improvised equipment to be used as educational material and improving the school's physical facilities. Most notably it offers the students for ability to use this equipment [5].

Objectives of the Study

The primary objective of this research was to design and develop a basic electro-pneumatic control trainer for use in learning industrial control in BIT courses as an instructional material.

This study was intended to address the issue of insufficient training facilities in State Universities and Colleges due to the very costly laboratory equipment, particularly in industrial control classes. Without the use of laboratory equipment that is capital-intensive and commercially available in these grades, a basic electro-pneumatic control trainer offers quality directions in the industrial control laboratory classes.

Another objective of this utility model was to provide a basic electro-pneumatic control trainer that will allow the students to experience the actual wiring of the electrical circuit and performing the pneumatic control of a certain task as well as enhance students' learning experience and appreciation of the subject as well as the course; and for the professors to assess the performance of their students. An additional goal of this utility model was to have greater reliability owing to the reduced amount of mechanical components needed to move or subject to wear and tear. Added purpose of this utility model was to have less planning and commissioning effort and cost, especially for complex control. One more goal of this utility model was to have less installation time, especially when using more contemporary, more compact assemblies such as valve terminals. An additional goal of this utility model was to use relays and contactors to easily and rapidly modify open-and closed-loop control policies. Extra purpose of this utility model was to facilitate data exchange between multiple control schemes.

MATERIALS AND METHODOLOGY

The trainer board was 24 inches by 24 inches by ¾ inch marine plywood. It was cost-effective, space-efficient and portable. It contained circuit breaker, plurality of din rails, plurality of terminal blocks, plurality of relays and relay holders, plurality of normality open and closed push buttons, plurality of utility box, plurality of base plates, plurality of 24VDC 3/2 way solenoid valves, plurality of 24VDC indicator lights, tubes duct, plurality of double-acting cylinders, plurality of clamps, and plurality of 24VDC proximity sensors. All the devices were totally exposed for easy installation and familiarization.

A basic electro-pneumatic control trainer comprised of a 24 inches by 24 inches by ¾ inch marine plywood (1) serves as a trainer board; a din rail 1 (3) and a din rail 2 (25) were screwed to the said board and holds the circuit breaker (2) and plurality of solenoid valves (24) respectively for stability purposes; a circuit breaker (2) was attached to din rail 1 (3) and connected to a 24VDC power supply for protection of the electrical circuit; a plurality of terminal blocks namely, terminal block 1 (4), terminal block 2 (9), terminal block 3 (14), terminal block 4 (17), terminal block 5 (20), terminal block 6 (23), terminal block 7 (26), terminal block 8 (31), terminal block 9 (36), terminal block 10 (41), and terminal block 11 (48) were integrally attached to the said with board, each terminal block includes a plurality of terminal ports adapted to interconnect each other; a plurality of utility box namely, utility box 1 (8), utility box 2 (13), and utility box 3 (47) were screwed to the said board and where the plurality of base plates namely, a base plate 1 (7), base plate 2 (12), base plate 3 (46) were fixed respectively which acts as casing of switches and pilot lights; a normally open push button switch 1 (5) and normally closed push button switch 1 (6) were inserted at the base plate 1 (7) for stability purposes; a normally open push button switch 2 (10) and normally closed push button switch 2 (11) were inserted at the base plate 2 (12) for stability purposes; a green pilot light (43), a red pilot light (44), and an orange pilot light (45) were inserted at the base plate 3 (46) for stability purposes; a relay holder 1 (16), relay holder 2 (19), and relay holder 3 (22) were attached to the said board which includes a plurality of terminal ports and holds the relay 1 (15), relay 2 (18), and relay 3 (21) respectively for stability purposes; a plurality of solenoid valves (24) which was electronically actuated control valve, operatively connected to the plurality of proximity sensors as signaling means and connected to a 60psi air compressor for air supply; a tube duct (27) attached to the said board which the pneumatic hoses ducted connecting the plurality of solenoid valves (24) going to plurality of double acting cylinders for safeguarding; a plurality of clamps namely, clamp 1 (32), clamp 2 (37), and clamp 3 (42) were attached to the said board and holds the plurality of double acting cylinders namely, double acting cylinder 1 (28), double acting cylinder 2 (33), and double acting cylinder 3 (38) respectively for stability purposes; a plurality of double acting cylinders were powered by compressed air having a corresponding operating piston which can be in extend or retract position; a plurality of proximity sensors namely, proximity sensor 1 (29) and proximity sensor 2 (30) were attached to double acting cylinder 1 (28), proximity sensor 3 (34) and proximity sensor 4 (35) were attached to double acting cylinder 2 (33), and, proximity sensor 5 (39) and proximity sensor (40) were attached to double acting cylinder 3 (38) which serves as an actuating device for pre-determined sequential signaling by the said operating piston.

The plurality of input and output devices terminals were pre-wired into the terminal blocks for faster installation and cost-effective for trainers' maintenance purposes. It was equipped with a low current circuit breaker to facilitate safe operations and eliminate damages to all the devices considering the hard to find and the high cost of the electro-pneumatic control components. It was cable of handling an industrial-like electro-pneumatic control wiring installation, troubleshooting, and commissioning.

Trainer Board Size	24 inches x 24 inches x ¾ inch marine plywood
Weight (including all devices)	7 pounds
Circuit Protection	CB-3 Amperes
Din Rail	Standard size
Terminal Block	6 Terminals, 5 Amperes
Push Button	Momentary Double Contact, 5Amperes
Utility Box	Standard size
Base Plate	¼ inch Marine Plywood Utility box size
Relay	24VDC holding coil - 8 Pins
Relay Holder	8 Pins, 10 Amperes
Solenoid Valve	3/2 Way Valve, 100 psi max, 24VDC Electrically Actuated
Pneumatic Tube	6mm diameter, 100 psi max, color blue
Wire Duct	25mm x 25mm, Standard
Double Acting Cylinder	16mm diameter, 8mm reach, 100 psi max
Proximity Sensor	24VDC, 2mm sensing capability
Pilot Light	24VDC source
Connecting Wire	#18AWG, Stranded Wire

Table 1. Technical specifications of the basic electro-pneumatic control trainer.

Methodology

This study utilized the developmental type of research. A basic electro-pneumatic control trainer comprised of:

A 24 inches by 24 inches by ¾ inch marine plywood (1) serves as a trainer board.

A din rail 1 (3) and a din rail 2 (25) were screwed to the said board and holds the circuit breaker (2) and a plurality of solenoid valves (24) respectively for stability purposes.

A circuit breaker (2) was attached to din rail 1 (3) and connected to a 24VDC power supply for protection of the electrical circuit.

A plurality of terminal blocks namely, terminal block 1 (4), terminal block 2 (9), terminal block 3 (14), terminal block 4 (17), terminal block 5 (20), terminal block 6 (23), terminal block 7 (26), terminal block 8 (31), terminal block 9 (36), terminal block 10 (41), and terminal block 11 (48) were integrally attached to the said with board, each terminal block includes a plurality of terminal ports adapted to interconnect each other.

A plurality of utility box namely, utility box 1 (8), utility box 2 (13), and utility box 3 (47) were screwed to the said board and where the plurality of base plates namely, a base plate 1 (7), base plate 2 (12), base plate 3 (46) were fixed respectively which acts as casing of switches and pilot lights.

A normally open push button switch 1 (5) and normally closed push button switch 1 (6) were inserted at the base plate 1 (7) for stability purposes.

A normally open push button switch 2 (10) and normally closed push button switch 2 (11) were inserted at the base plate 2 (12) for stability purposes.

A green pilot light (43), a red pilot light (44), and an orange pilot light (45) were inserted at the base plate 3 (46) for stability purposes.

A relay holder 1 (16), relay holder 2 (19), and relay holder 3 (22) were attached to the said board which includes a plurality of terminal ports and holds the relay 1 (15), relay 2 (18), and relay 3 (21) respectively for stability purposes.

A plurality of solenoid valves (24) which was electronically actuated control valve, operatively connected to the plurality of proximity sensors as signaling means and connected to a 60psi air compressor for air supply.

A tube duct (27) attached to the said board which the pneumatic hoses will be ducted connecting the plurality of solenoid valves (24) going to plurality of double-acting cylinders for safeguarding.

A plurality of clamps namely, clamp 1 (32), clamp 2 (37), and clamp 3 (42) were attached to the said board and holds the plurality of double-acting cylinders namely, double-acting cylinder 1 (28), double-acting cylinder 2 (33), and double-acting cylinder 3 (38) respectively for stability purposes.

A plurality of double-acting cylinders were powered by compressed air having a corresponding operating piston which can be in extend or retract position.

A plurality of proximity sensors namely, proximity sensor 1 (29) and proximity sensor 2 (30) were attached to double acting cylinder 1 (28), proximity sensor 3 (34) and proximity sensor 4 (35) were attached to double acting cylinder 2 (33), and, proximity sensor 5 (39) and proximity sensor (40) were attached to double acting cylinder 3 (38) which serves as an actuating device for pre-determined sequential signaling by the said operating piston.

The basic electro-pneumatic control trainer utilizes 24VDC as a power supply for the electrical circuit which was connected to the circuit breaker (2) and a 60psi compressed air for pneumatic control as air supply which was connected to the plurality of solenoid valves (24).

The basic electro-pneumatic control trainer having a plurality of input and output devices terminals were pre-wired into the plurality of terminal blocks for faster installation and easy maintenance of the trainer.

This research was limited to the development of a basic electro-pneumatic control trainer. This utility model was further demonstrated following the instructional module in basic electro-pneumatics to the faculty members of the College of Technology, Pangasinan State University – Lingayen Campus teaching BIT major in Electrical, Electronics and Mechanical Technology. Additionally, interview and consultation with the faculty members to assess the functionality of the said utility model was conducted.

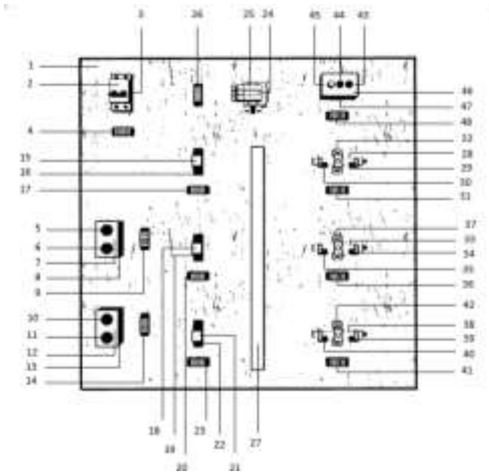

Figure 1. Front view of the utility model, which shows the design and its parts.

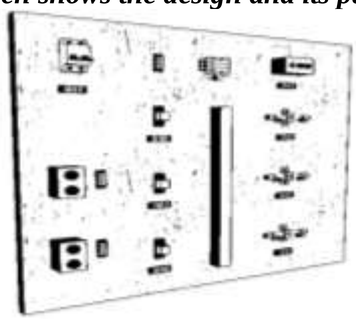

Figure 2. Perspective view of the utility model.

Results and Discussion

Electro-pneumatic control incorporates electrical and pneumatic systems and was used more commonly for big applications. The signal medium was the electrical signal with a DC source in electro-pneumatics. Compressed air was the work medium. After completing this research, after installing and fixing various solenoid valves and components, providing electrical connections and regulating the pressure of 60psi, the valves were found to execute the sequential order given through the pushbuttons. No short circuit was noted while operating on it in any of the electrical wirings. The voltages in operation were 24VDC. Solenoid actuation triggered the final valve control. Electro-pneumatic system control was performed using a relay combinations. Used either normally closed or normally open relay to transform signal input from sensors and switches to the number of output signals. The output signals were finally delivered to the solenoids that activate the final control valves that control the motion of different cylinders and give the pilot lights a signal.

After demonstration, interview and consultation with the faculty members of the College of Technology, Pangasinan State University – Lingayen Campus teaching BIT major in Electrical, Electronics and Mechanical Technology, the said utility model can perform all the activities listed in the instructional module in basic electro-pneumatics which were also parallel to the real world industry of automation.

This research output was granted an Industrial Design (ID) patent by the Intellectual Property Office of the Philippines while still waiting for subsequent formality examination report as a pending application for a Utility Model (UM) patent by the same office.

Conclusion

Upon completion of this study, users can learn how to read and comprehend pneumatic circuit diagrams and acknowledge global norms, acknowledge and comprehend pneumatic and electrical parts and their features, build easy electro-pneumatic circuits, read and comprehend circuit diagrams for electro-pneumatic controls, design circuits for multi-actuator control schemes, comprehend feature, design, technical information and symbols for pneumatic and electronic sensors, include control circuit timer features, identify how electro-pneumatic interfaces are interconnected, compare electro-pneumatic alternatives in implementation and, finally, schedule, design and produce practical training equipment.

Recommendation

In this study, electro-pneumatic control system can be used in many applications, automation can be simple even with complicated procedures, productivity can be increased that leads to a reduction in manufacturing time, errors can be detected and fixed, After the interview and consultation to the faculty members of College of Technology, Pangasinan State University – Lingayen Campus teaching BIT major in Electrical, Electronics and Mechanical Technology, it was recommended that the design and operation of the electro-pneumatic control system would have been much easier if the author had used Programmable Logic Control (PLC) and the scheme itself could be remotely controlled. So the proposal was to use PLC that would be much easier to monitor and simulate any control system than to use other controllers because PLC is a computer intended for industrial activities. As it is simple to comprehend, the other recommendation is to use Ladder diagram language with PLC.

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