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ELECTROPNEUMATIC POSITIONING SYSTEM CONTROL WITH THE LEGENDARY LOGO! PLC

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***Abstract*— This project deals with the construction of an integrated electropneumatic system in which the design and implementation of its control method is carried out. In particular, the position of a pneumatic cylinder is controlled by a Siemens LOGO! PLC along with a position sensor.**

The electropneumatic system consists of a 5-way and 3-position (5/3) electrically guided valve, a double acting pneumatic cylinder with magnet and 100mm stroke length, an air compressor for the supply of the system with compressed air, a magnetic cylinder position sensor, a Siemens LOGO! RC 24 PLC, buttons for system activation as well as power supplies for the electric parts of the system.

The system implementation began gradually, in the form of 4 scenarios. Purpose of paper is the theoretical review of the individual elements of this system as well as the construction and programming, through the Function Block Diagrams (FBD) programming language. In addition, the points in which electropneumatic systems are used in industry and shipping are identified along with the points in which the programmable logic controller selected for this system excels. All in all, a low cost solution for pneumatic cylinder position control applications is presented which is also easy to program.

I. INTRODUCTION

Automation systems are parted in three main types: pneumatic, electrical and hydraulic. This system deals with the first two types. Pneumatic systems are a field of engineering that has been around for many years and deals with physical elements such as air, pressure, density, volume and temperature [1] [2]. Taking advantage of the principles of gases and applying appropriate methods and tools, they use compressed air to solve various mechanical problems. On the other hand electrical systems use electrical current to convey or receive signals.
Pneumatic systems use compressed air as a means of transporting the movements in the same way as hydraulic systems use liquids. Their ability to perform in strong forces is less than that of hydraulics. On the other hand, their working speed is much better, so they are widespread in shipping and industry.
Electrical systems use electrical signals to cause movements and shifts to system outputs. These systems are vulnerable to static forces and require special precautions against overloads. Instead, they have greater reliability and better speeds than other types of automation, while they can easily control complex systems over long distances. The following table shows the comparison of these systems [3].

	Hydraulic	**Pneumatic**
Energy source	Electric motor or diesel driven	Electric motor or diesel driven
Energy storage	Limited (accumulator)	Good (reservoir)
Distribution system	Limited basically a local facility	Good. can be treated as a plant wide service
Energy cost	Medium	Highest
Rotary actuators	Low speed. Good control. Can be stalled	Wide speed range. Accurate speed control difficult
Linear actuator	Cylinders. Very high force	Cylinders. Medium force
Controllable force	Controllable high force	Controllable medium force
Points to note	Leakage dangerous and unsightly. Fire hazard	Noise

Table 1: Comparisons of electrical, hydraulic and pneumatic systems

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Combination of pneumatic and electrical circuits creates a kind of systems, which offers a plethora of advantages and are called electro-pneumatic. In these systems, once the electrical current is introduced, technologies such as computers, PLCs or other types of microprocessors and electronic sensors can be used to make the system intelligent.

Using a PLC the system wins agility because it is possible to execute all the needed logic to sequence the movements of the actuators. Furthermore, simulation of components like counters and timers can be achieved so as to control the status of the system or simulate and create the system as many times as necessary.

II. METHODOLOGY

As a first step, it was necessary to determine how all the mechanical parts of the system work, how they are connected and cooperate with each other. This resulted in the creation of scenario 1 where the pneumatic part of the system, which consists of: a 5-way and 3-position valve with closed centers which is controlled without its electric actuation, a double acting pneumatic cylinder and the compressor.

The valve consists of 2 screw-shaped rotary switches which can be rotated by means of a screwdriver. These two switches have the capability, once they are rotated, to move the gasket held by a spring upward and thereby allow the position of the valve to be changed.

In Scenario 2 as in the previous one, the operation of the system had to be determined, using this time the electrical actuation of the valve instead of the manual. To do this, coils should be installed to activate the valve.

For this operation, the following components were needed: Electro-pneumatic valve with coils, double acting pneumatic cylinder, an air compressor, a power supply for the operation of the coils and finally two switches for activating and deactivating the coils.

The third scenario is similar to the previous one. In this case, the switches of the previous scenario were replaced by the programmable logic controller LOGO!. The PLC is responsible for activating and deactivating the coils thus it is programmed with a suitable program.

Finally, in the last operating mode, a check had to be made as to how the sensor selected to control the piston position is operating. By using a sensor on the pneumatic cylinder, the concept of the closed system is introduced. This means that as soon as the system starts to run its duty cycle, the PLC will receive a signal at some point from the sensor that the piston has reached the desired position. Then the command is either to return the plunger to its original position or to stop at the point where the sensor is located.

In this operation the following parts were needed: an electro-pneumatic valve with coils, a double acting pneumatic cylinder, an air compressor for supplying the system with compressed air, the PLC LOGO!, two power supplies, one for the operation of the coils and the other to supply LOGO!. Last but not least, a sensor was used to read the piston position, giving a voltage to the PLC and a switch which command the start of the programmed operation.

The whole system consist of the following components [4][5][6]:

a) 1x 5-way / 3-position valve with closed centers.
b) 2x Coil 24V DC.
c) 2x Electrical connector.
d) 2x Mechanical actuator for Normally Closed (N.C.) solenoid valve.
e) 1x Reciprocating air compressor.
f) 1x Double acting magnetic cylinder.
g) 1x Siemens LOGO! 24RC DC24V (6ED1052-1HB00-0BA0).
h) 1x Reed type sensor.
i) 1x 240V~50/60Hz / 24V~1A Power supply.
j) 1x 230V~50Hz / 24V~600mA Power supply.
k) 1x Normal closed (N.C.) push button.
l) 2x On/off Switch.

Figure 1: All system components.

Construction

Initially, a piece of plywood, 25x56 cm was used for seating the system. The electropneumatic valve and the pneumatic cylinder were screwed onto it. In addition, air pipes Ø 4x6 were used to pass the air from the air compressor to the valve and from there to the pneumatic cylinder. The air compressor was then activated until its manometer reached about 5 bar. Then the manual control of the valve began

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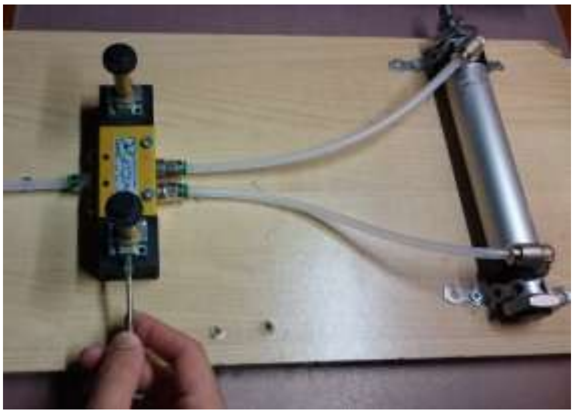

Figure 2: Scenario 1 system implementation.

Moreover, in this scenario, the electrical actuation of the valve was used instead of manual. During this phase the coils were placed on the electromagnetic valve. In order to operate the coils should be assembled with the special plug that snaps onto them and ends into two wires. These cables are connected to a 24V DC power supply. Two on/off switches were inserted between the coil cables and the power supply. These switches were used to activate and deactivate the coils but also to simulate the function that was implemented in the next Scenario by LOGO!. The figure below shows the construction of Scenario 2.

Figure 3: Scenario 2 system implementation.

During this scenario, the Siemens LOGO! RC 24 was added into the system!. The function is again on / off using instead of switches, a LOGO! with an appropriate Function Block Diagrams program. This phase together with the PLC uses a 24 V DC power supply as well as a pushbutton which will signal the piston movements as shown in Figure 4.

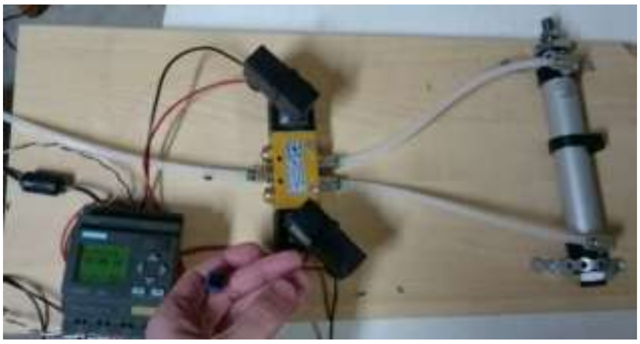

Figure 4: Scenario 3 system implementation.

Initially, the assembly of electrical components and the LOGO! as shown in Figure was performed. The first power supply is used to supply power to the PLC and is connected to the PLC L1 and N terminals. The pushbutton is an input to the system whereby one end is connected to the terminal I1 and the other to the power supply. This switch, as long as it is pressed, signals the PLC input, and once it is left, the input is deactivated. The second power supply was then used to power the coils.

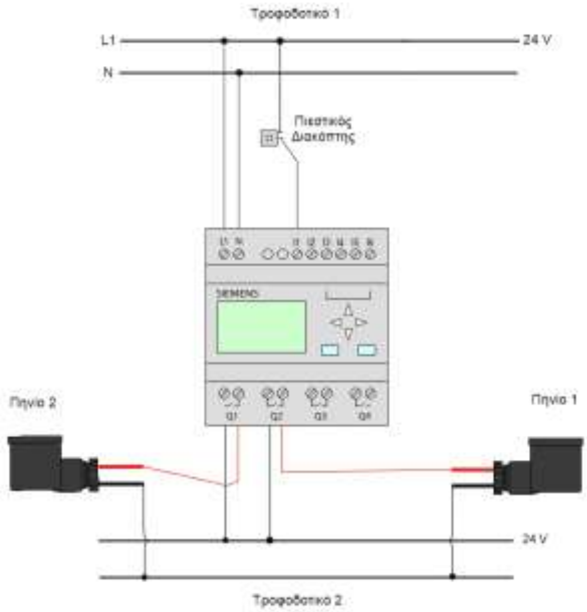

Figure 5: Connection of electrical components in scenario 3.

At this point, a Reed type sensor with the help of a special mount, is placed on the cylinder. It is assumed that there is a magnet on the plunger that once it reaches the point of the sensor, creates a magnetic field, closes a circuit, illuminates a LED indicator light and outputs a voltage which the PLC reads as an input.

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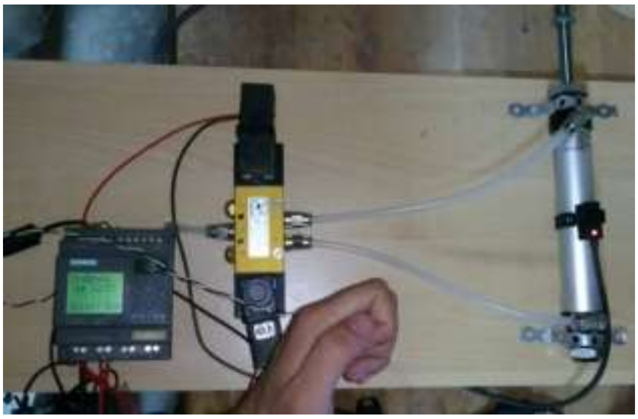

Figure 6: Scenario 4 system implementation.

The figure below shows the connection of the electrical elements of Scenario 4. As mentioned above, the only difference with the previous scenario is the connection of the Reed sensor whose one terminal is connected to the power supply L1 and the other to the terminal I2 of the LOGO!.

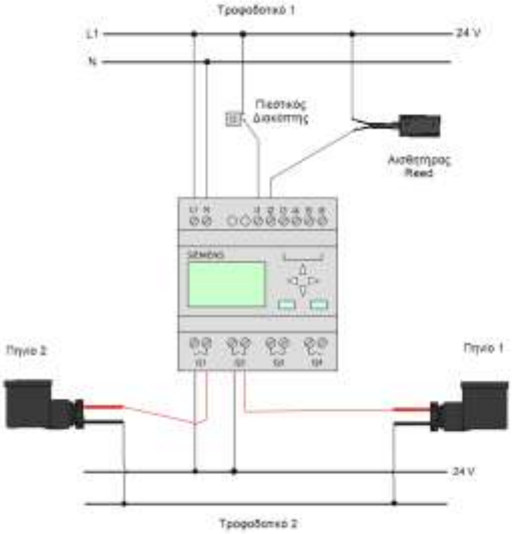

Figure 7: Connection of electrical components in scenario 4.

Programming

The Siemens LOGO! PLC offers two main ways of programming, ether using the embedded display and control panel or by a special software called LOGO!Soft Comfort [6]. The first method supports the Function Block Diagrams programming language and the other supports FBD and Ladder Diagram language. In this case the first method was chosen because of the practicality and flexibility it has to offer.

As far as the system is concerned the programming starts in third scenario. The outputs of the system are 2 coils which were placed on the terminals Q1 and Q2. After that, function blocks containing the appropriate commands were set as well as the system inputs. In some cases a variable is defined, which is the time required to perform that function. Time can either have positive or negative sign. In the following figure, the scenario 3 code is represented as it is shown in the LOGO! Screen:

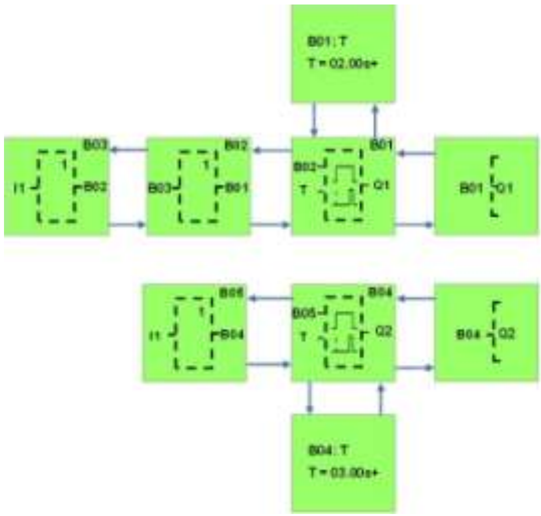

Figure 8: Function Block Diagrams of Scenario 3 as shown in LOGO!.

In the last scenario, the exact same procedure was followed as in Scenario 3 programming. Initially outputs were defined, followed by the blocks containing the commands. Some of the commands asked to set time to be executed, while in some others the letter "x" is indicated, stating that from this point on are no other connected functions. Figure 9 below shows the scenario 4 code as it is shown in the LOGO! Screen:

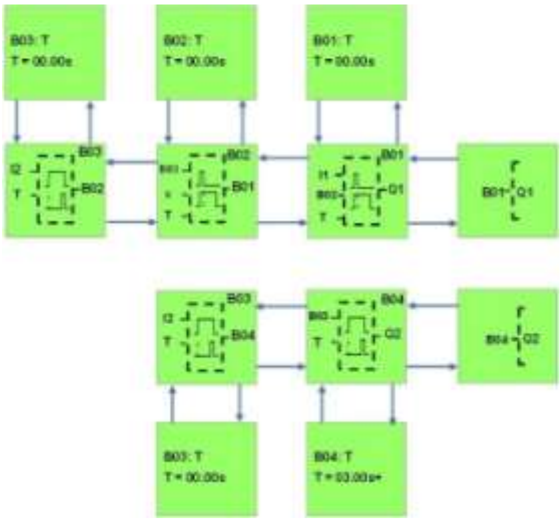

Figure 9: Function Block Diagrams of Scenario 4 as shown in LOGO!

III. CONCLUSIONS

The construction and control of the electropneumatic system was considered successful. The main goal was the correct assembly of the system and to create appropriate programs, in FBD programming language for the scenarios.

The first scenario was intended to give a full and correct understanding on how the pneumatic elements of the system work and interact. An alternative control method, manual control. This can be applied in cases where there are no electrical components for use in the system but also in emergency situation where they stop functioning.

In the second scenario the electro-pneumatic valve coils were introduced, which were activated and deactivated via two switches. This scenario shows how the electrical actuation of the valve is achieved as well as how the electrical and pneumatic components in electropneumatic valves interact.

Furthermore, the third scenario deals with the electronic part of the system. It was found out that the electrical actuation of the valve is fully compatible with the selected Siemens LOGO! PLC. The system was also able to fully recognize and execute the given commands of LOGO!. Also, the proper programming was implemented through the FBD programming language, directly on the PLC using the embedded display and control panel.

The display offers the possibility of on-site programming and has proven to be a great asset. Any engineer using this system is able to build it on site, e.g. an engine room, a production line or any other point with difficult access. Also he or she can repair it by having direct contact with it. Moreover it does not require the use of additional tools and devices for programming such as a computer and cables, which greatly facilitates the work of the engineer.

In the last scenario, a Reed type sensor was installed. These are widely used for piston position control. In addition, they are very low cost sensors, easily placed on the cylinder and can be used in ether continuous or alternating current. Its power consumption is very low.

The 5-way / 3-position electropneumatic valve proven to be the case for double acting piston control. The valves are capable of stopping the piston in the middle of its travel but also moving it from one point to another, provided the appropriate sensors are used. This concludes that they are ideal for use in safety systems where the movement of an actuator has to be abruptly stopped, for example when closing a door.

However, during the operation of the system it was found that the piston could not stop exactly at the point where the sensor is placed. This is due to the excessive pressure the compressor gives to the piston. The operating pressure was set at 4-5 bar (recommended by the manufacturer 3-7 bar) [4]. Thus, in order to stabilize piston movement, it was necessary to adjust the airflow through the pressure regulator located on the compressor valve.

This electro-pneumatic system can be applied in many areas [7][8]. Especially with regard to the shipping industry, this construction can become an important tool for the ship's engineers. Finally, this system is a very economical solution. The PLC LOGO! is a model that can be found very easily on the market at very low prices. Also due to its inveteracy, it can be found in warehouses of industries or ships and from there to be properly utilized.

As far as the system is concerned, some proposed changes and improvements could be as follows:

- Use electropneumatic valve of different roads and positions. This would have the effect of completely changing the structure of the system and its operation.
- Use more than one or a different type of actuator.
- Use a different sensor to locate the piston position. In particular, the LVDT analog sensor could be used. In this case, a newer LOGO! model should be used as well as an expansion. That's because 0BA0 does not support analog inputs and outputs. This analogue sensor should be installed and run parallel to the piston. This will allow continuous and complete control and the PLC will recognize its position at any time due to the constantly changing voltage at the output.
- Use a newer LOGO! (beyond 0BA0). In each newer model (0BA1 ... 0BA8), Siemens has gradually introduced more and more functions to its PLCs. This will result in better programming and greater variety of movements to the user.
- Use more inputs and sensors to the system.
- Weights and loads can be placed on the rod end so as the behavior of the system can be studied.

On the other hand, if the construction itself is used, some changes can be made to the planning. The scenarios implemented in this work can be done through other PLC commands. There can still be a change in the sequence of movements. That is, there are changes in the way that LOGO! manage the signals it receives from the inputs and changes the order of the movements.

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