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Laboratorijska elektro-pneumatski upravljana postavka

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Proučavanje dinamičkog ponašanja objekata ili sistema kao odgovor na zadate uslove ne može se uvek lako ili sigurno primeniti u stvarnom životu. Računarske simulacije u inženjerstvu su veoma važne jer na siguran i efikasan način rešavaju stvarne probleme. Pružaju važan metod analize koji se lako proverava i razume. U svim granama industrije simulaciono modeliranje pruža dragocena rešenja dajući jasan uvid u složene sisteme. Laboratorijska postavka predstavljen u ovom radu je model mašine za savijanje pneumatskog lima. Elektro-pneumatska kontrola kretanja ovog sistema modelira se i simulira u softveru FluidSim. Ovaj sistem je fizički realizovan na FTN Čačak koristeći osnovne pneumatske i električne komponente i PLC. Opisana laboratorijska postavka u ovom radu korišćena je u nekoliko predmeta kao laboratorijska vežba koja studenata pomaže u razumevanju rada sličnih sistema.

Ključne reči: Laboratorijska Postavka; Projektovanje; Simulacija; Programiranje; FluidSim

1. UVODNA RAZMATRANJA

Simulacije se mogu definisati kao računski programi koji prikazuju rad nekog sistema sa mogućnošću promene parametara i praćenja ishoda programa. [1]

Računarska simulacija ima ogroman potencijal za unapređenje obrazovanja i nauke. Kompjuterske simulacije pružaju interaktivne, autentične i značajne mogućnosti učenja za studente, jer olakšavaju učenje apstraktnih pojmova, kroz vizuelno i trenutno dobijanje povratnih informacija o promenama koje su nastale na sistemu. [2]

Još jedan primer primene simulacija je povezivanje i bolje razumevanje teorije i prakse. Korišćenjem računarskih simulacija u nastavnim procesima gde god je to primenljivo, studenti razvijaju inženjerski način razmišljanja vezan za probleme na koje naiđu i takođe mogu dobiti priliku da vide kako se proces ponaša u realnom vremenu. [3]

Prednosti simulacija su takođe u razumevanju vrednosti i ograničenja numeričkih metoda koje se koriste u sistemu, kao i mogućnost optimizacije sistemskog rešenja u pogledu troškova, vremena i energije.

Otkako se komprimovani vazduh počeo koristiti kao pokretač za fizički rad, dostupan je u skoro svim industrijskim instalacijama. Stoga su pneumatski cilindri i ventili postali konkurentni u mnogim aplikacijama kao što su kontrola kretanja materijala, hvataljke, robotika, industrijski procesi, prerada hrane itd. Zbog toga je proučavanje simulacionih i upravljačkih modela ovih aktuatora rasprostranjeno u edukaciji inženjera. [4]

Upravljanje pneumatskim komponentama pomoću električnih impulsa poznato je kao elektro-pneumatika.

U ovom radu je predstavljen dizajn laboratorijske postavke elektro-pneumatskog sistema, koji oponaša industrijski proces mašine za savijanje limova.

Sistem je napravljen koristeći prave industrijske komponente i omogućava primenu praktičnih znanja i veština koje su lako primenljive u praksi.

Simulacija rada pneumatskog sistema realizovana je u softveru FluidSim koji je sveobuhvatan softver za simulaciju sistema za kontrolu fluida. Softver FluidSim pomaže studentima da analiziraju i reše probleme sa relevantnim znanjem i poboljšaju svoje praktične sposobnosti. [5]

Programabilni logički kontroler (PLC) je dodat u sistem. Na ovom obrazovnom kompletu realizovan je program da bi se postigla potrebna sekvenca.

2. STRUKTURA LABORATORIJSKE POSTAVKE

Kontrola kretanja sistema obezbeđena je primenom koračnog režima upravljanja. To podrazumeva se kretanje odvija sekvencijalno (korak po korak) gde su uslovi za prolazak kroz korake definisani aktivnošću određenih ulaza. U elektro-pneumatskom upravljačkom sistemu mogu se identifikovati tri glavna dela: pneumatski deo, upravljački deo (električni) i napajanje. Upravljački i napojni deo su električni. [6]

Dizajn elektro-pneumatskog sistema za savijanje lima prikazan je na slici 1. Oprema koji se koriste za izradu ovog sistema su kompresor, jedinica za pripremu vazduha, regulator pritiska, cevovod, obrazovni set „Mašina za savijanje lima", PLC kontroler i računar sa potrebnim softverima.

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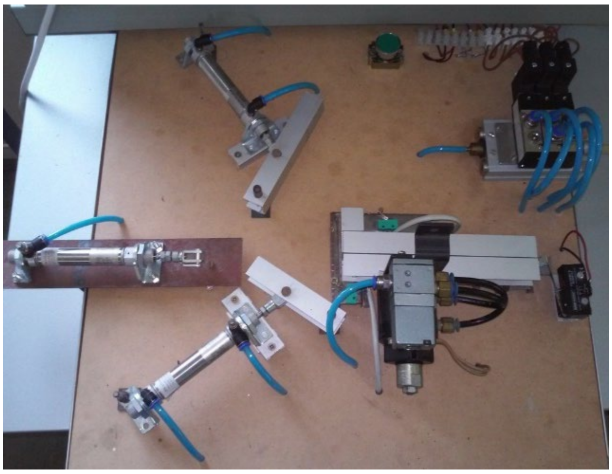


Slika 1. Electro-pneumatska postavka za savijanje lima[3]

Osnovna funkcija kompresora je pretvaranje isporučene mehaničke energije u energiju komprimovanog vazduha.

Glavne karakteristike kompresora su protok, količina komprimovanog vazduha i pritisak postignut nakon kompresije. Klipni kompresor sa pravolinijskim kretanjem klipa, koji se uglavnom koristi u industriji, koristi se i za pokretanje ovog obrazovnog sistema. Komprimovani vazduh i vlaga povećavaju brzinu habanja površine i zaptivanja, smanjuju efikasnost i radni vek pneumatskih komponenata. Takođe, nestabilan pritisak ima negativan uticaj na rad kompletnog sistema.

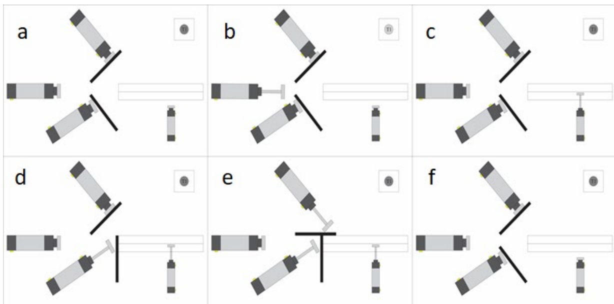
Kada govorimo o kompresorima, pre ulaska u pneumatske uređaje potrebno je da vazduh bude adekvatno tretiran. Pripremna grupa je deo pneumatskog sistema koji odvlažuje, podmazuje, čisti vazduh i reguliše njegov pritisak. Pripremna grupa se sastoji od filtera, zauljivača i regulatora pritiska. Efikasni sistemi za prečišćavanje komprimovanog vazduha smanjuju "tačku rose" vazduha i uklanjaju čestice koje mogu negativno uticati na rad sistema, kao što su prašina i proizvodi korozije, voda, para, ulje za kompresore. Zauljivač se koristi za ubrizgavanje ulja u obliku fine magle u sistem prenosa vazduha. Uloga regulatora pritiska je da obezbedi stabilan željeni radni pritisak. Regulator pritiska prigušuje oscilacije pritiska usled promenljive potrošnje vazduha koja se javlja kao smetnja na izlaznoj strani regulatora i smanjuje vazdušni pritisak sa glavne linije na potrebnu vrednost radnog pritiska.

Glavne pneumatske i električne komponente obrazovne postavke „Mašina za savijanje lima“ su: jednostrani i dvostrani cilindri, elektro-magnetni razvodnici, taster, granični prekidači i računar sa softverom. Pneumatski linearni motori - cilindri pretvaraju energiju komprimovanog vazduha u mehanički rad. U pneumatskim sistemima, cilindar je obično izvršni element. Mogu biti sa jednosmernim (jednosmerni cilindar) ili dvosmernim (dvosmerni cilindar) režimom rada. Jednosmerni cilindri imaju mogućnost upravljanja vazduhom samo sa jedne strane klipa, pri čemu se klipnjača izvlači i obavlja mehanički rad. Vraćanje klipa u početni položaj vrši se oprugom na drugoj strani klipa ili njegovom težinom. Dvosmerni cilindri imaju mogućnost upravljanja vazduhom sa obe strane klipa, tako da cilindar ima radni hod u oba smera. Za upravljanje cilindrom dvostrukog dejstva koristi se pneumatski razvodnik.

Razvodnici su ventili koji prolaze, zatvaraju i usmeravaju tok fluida. Tip razvodnika određuje se brojem priključaka, brojem položaja (stanja), načinom aktivacije, načinom vraćanja i dimenzijom priključaka. Oznaka tipa razvodnika odgovara broju priključaka i broju položaja. U realizaciji opisanog obrazovnog seta korišćeni su elektromagnetno kontrolisani razvodnici vazduha tipa 5/3 i 3/2. Tip 3/2 označava tri priključka i dva položaja: jedan priključak se povezuje sa dovodom komprimovanog vazduha; drugi priključak služi za rasterećenje, a treći priključak se povezuje sa cilindrom. Ventil ima dva položaja: punjenje ili pražnjenje cilindra. Potrebna veličina ventila može se izračunati kada se poznaju osobine cilindra i primene.

Radeći na ovoj obrazovnoj postavci, studenti se upoznaju sa principima rada primenjenih pneumatskih komponenata. Uče da projektuju pneumatske sisteme, simuliraju njihov rad, i što je najvažnije uče da implementiraju takav sistem koristeći PLC i softver za programiranje. [7]

Primer koji ova postavka reprezentuje je proces savijanja lima. Ovaj zadatak se sastoji od nekoliko koraka savijanja lima kako bi se napravio „J“ profil. Kompletna sekvenca zadatka savijanja lima prikazana je na slici 2.



Slika 2. Sekvence kod mašine za savijanje lima [3]

Redosled operacija sastoji se od sledećih koraka: (a) Ručno postavite lim u obliku trake u mašinu. Ciklus započinje pritiskom na taster T1; (b) jednosmerni cilindar C gura traku od lima dok se ne postigne položaj CX; (c) Cilindar C se zatim vraća u početni položaj; (d) jednosmerni cilindar D priteže lim u alat; (e) Zatim cilindar dvostrukog dejstva A savija traku dok ne dostigne položaj AX, dvosmerni cilindar B tada savija lim do graničnog položaja BX; (f) Na kraju ciklusa, svi cilindri se vraćaju u početni položaj i gotovi „J“ profila može se izvaditi.

3. PROJEKTOVANJE PNEUMATSKOG SISTEMA

Pneumatski sistem se sastoji iz dva dela:

1. pneumatike
2. elektrike.

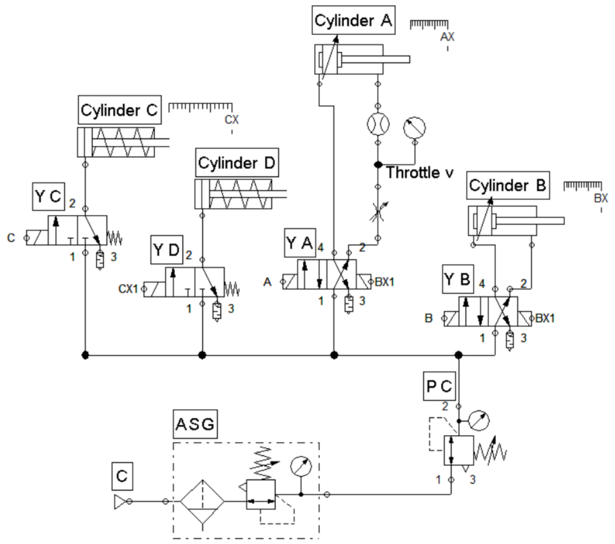
Simulacija pneumatskog sistema napravljena je u programu FESTO FluidSim (slika 3).

FluidSIM je softver prilagođen za modeliranje, simulaciju i proučavanje elektro-pneumatskih, elektro-hidrauličkih, digitalnih i elektronskih kola. Sve navedene funkcije mogu se lako integrisati, kombinujući različite metode i znanja na jednostavan i dostupan način.

Softver je intuitivan za izradu šema veze sa potpunim opisom svih komponenti, standardnih simbola i karakteristika komponenata [8]. Pneumatske komponente su objašnjene tekstualnim opisima, simbolima, slikama i animacijama koji ilustruju principe rada [9].

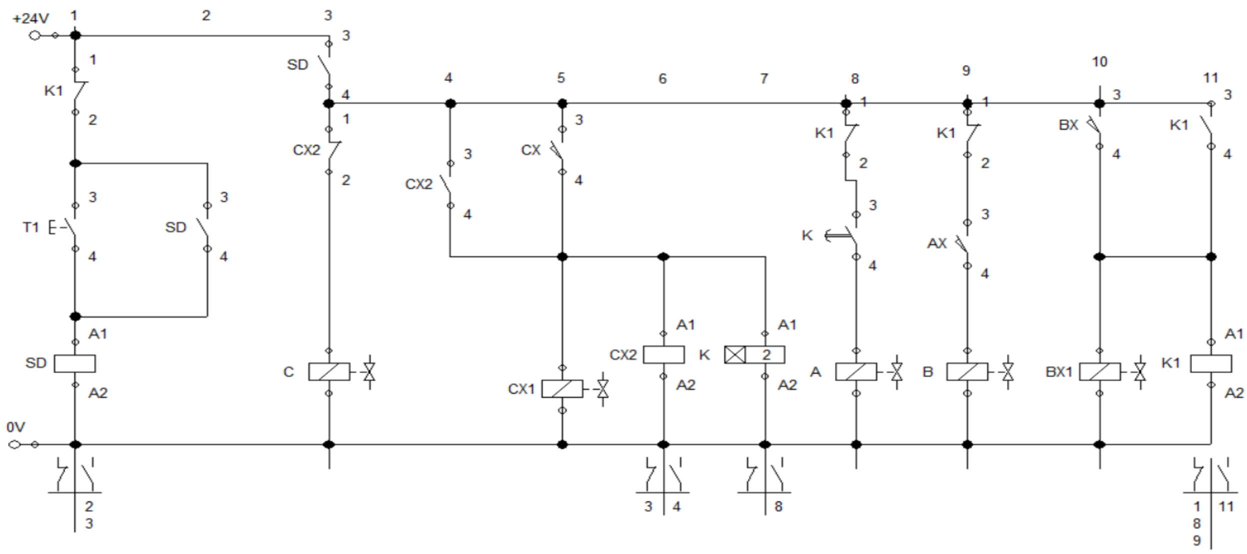
Električna šema se može realizovati na razne načine. Svaki student mora primeniti svoju logiku tako što će dizajnirati i projektovati svoju električnu šemu za željeni sistem, kako bi on odradio zadate korake.

Ova električna šema koristiti samo u simulaciji, tako da studenti mogu da koriste sve električne komponente za koje misle da su im potrebne ili u praksi (u našem primeru PLC električna šema veze). Jedna od električnih šema koja odgovara opisu zadatka i može se simulirati prikazana je na slici 4. Pritiskom na taster (F9) započinje simulacija, dok se taster T1 koristi za pokretanje šeme koji se simulira. Ova simulacija pomaže studentima da vide da li njihova logika funkcioniše ili ne.



Slika 3. FluidSim šema pneumatskog sistema [3]

Nakon što logika radi u simulaciji, pneumatske i električne šeme mogu se primeniti na stvarnom sistemu (PLC program).



Slika 4. Električna šema sistema [3]

Sastavni deo EPM sistema su komponente prikazane u Tabeli 1, za pneumatsku i električnu vezu sistema. Svaki simbol se može podesiti kao fizička komponenta u sistemu. Dvostrani pneumatski cilindar A (PCU-16-50-DD-A) ima maksimalni hod 50 mm, prečnik klipa 16 mm i prečnik šipke 5 mm [10]. Ti parametri moraju biti konfigurisani u konfiguratoru cilindara.

Elektromagnetni ventili moraju biti konfigurisani kao i cilindri. Parametri moraju biti u skladu sa dokumentacijom za svaki ventil u sistemu. Svaka komponenta mora biti pravilno konfigurisana da bi se simulacija mogla pravilno obaviti.

Tabela 1. Komponente koje čine EPM sistem [3]

Redni broj	Oznaka	Opis
1	C	Kompresor
1	ASU	Pripremna grupa
2	Cylinder A, B	Cilindar dvostrukog dejstva
2	Cylinder C, D	Cilindar jednostrukog dejstva
2	AY, BY	4/2-razvodnik
2	CY, DY	3/2 -razvodnik
1	T1	Taster
3	AX, BX, CX	Granični prekidač
1		Napajanje 24V
1		Napajanje 0V
1	SD	Relej za samodržanje
8	C, CX1, A, B BX1	Elektromagnet razvodnika
2	K, K1	Relej
1	K	Tajmer relej
1	PLC	PLC Direct Logic 05

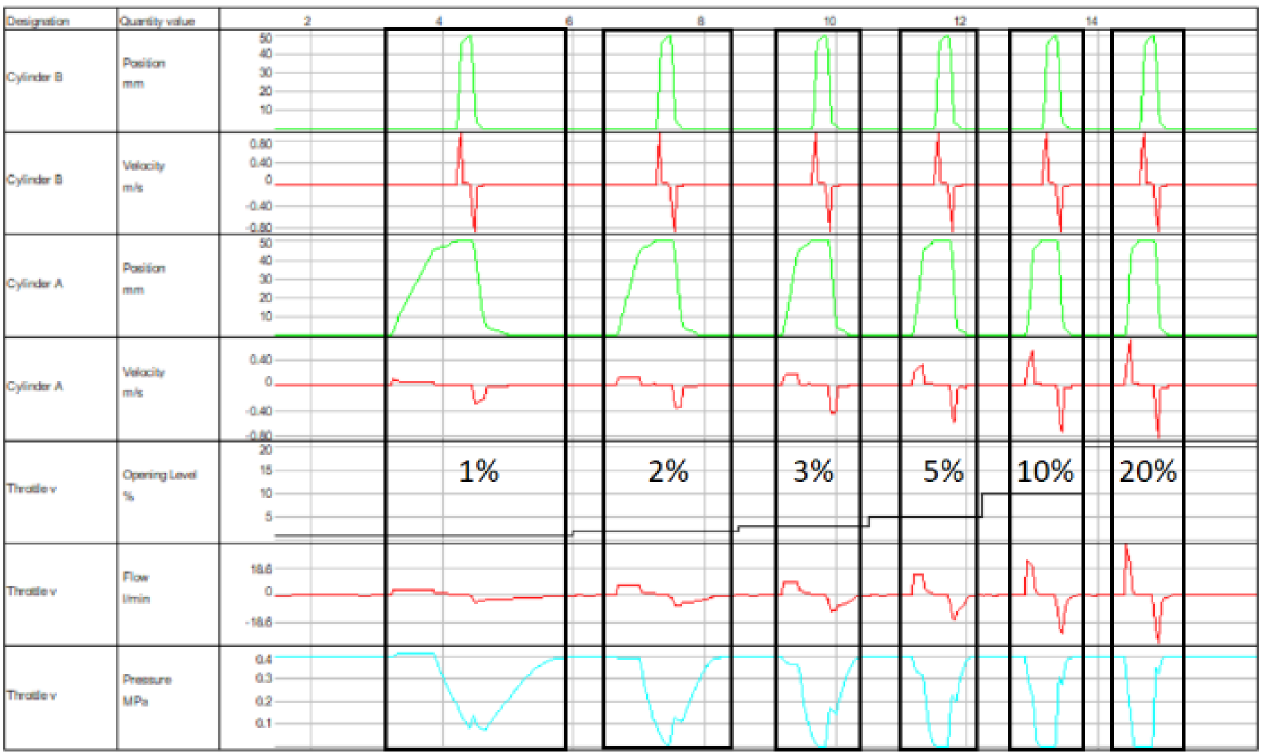
4. SIMULACIJA

Softver FluidSim za simulaciju sistema je veoma lak za modeliranje sistema i poseduje jednostavne opcije. Različite računarske simulacije i eksperimenti mogu se izvesti pomoću razvijenog modela prikazanog na slici 3. Sledeći rezultati su dobijeni da bi se potvrdila funkcionalnost sistema.

Pored testiranja logike, program FluidSim takođe može simulirati stanja sistema na vremenskoj osi. Ta stanja mogu biti različiti parametri: brzina i položaj cilindra, pritisak i protok na željenoj komponenti.

U ovom radu prikazano je ponašanje cilindra promenom protoka na njegovom jednom ulazu. Protok je menjan od 1% do 20% u šest koraka (1%, 2%, 3%, 5%, 10%, 20%). Grafik sa položajem i brzinom željenog cilindra A i B, kao i grafiko pritiska i protoka na prigušnom ventilu dati su na slici 7.

Ovaj grafik sadrži brzinu rada cilindra proporcionalnu protoku kroz njega. Kako se protok povećava, tako i brzina posmatranog cilindra raste, a potrebno je i manje vremena za delovanje.



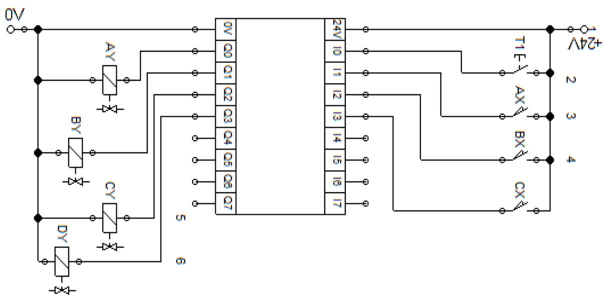
Slika 7. Dijagram pozicije i brzine rada cilindara A i B u zavisnosti od prigušenja na prigušnom ventilu. [3]

Cilindar A ima regulaciju protoka na jednom ulazu, ali to utiče na oba ulaza kao što prikazuje grafik. Prigušni ventil na jednoj strani smanjuje promenu protoka u cilindru sa obe strane (izvlačenje i uvlačenje).

Ovom vrstom simulacije brzina rada cilindra se može prilagoditi vrednosti koja se mora postići na stvarnom sistemu. Brzina rada cilindra A u analiziranom sistemu je važna, jer ako nije dobro podešena, može doći do sudara sa drugim cilindrom ili mehaničkim delom sistema.

5. PLC PROGRAM

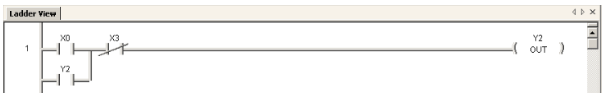
Programabilni logički kontroler (PLC) je hardver koji može da zameni složene električne šeme. Lako je promeniti logiku i prilagoditi sistem ispravnom radu. Električna šema projektovana sa PLC-om prikazana je na slici 8. Odmah je očigledno da je ova šema daleko jednostavnija od prethodne prikazane na slici 4.



Slika 8. Električna šema veze sa PLC-om.

PLC program sadrži svu logiku u softveru koja je urađena u shemi prikazanoj na slici 4. Programski blokovi su prikazani u nastavku.

Taster T1 je povezan na ulaz X0. Ovaj ulaz je programiran za aktiviranje izlaza Y2 koji je povezan na CX ventil koji aktivira cilindar „C“ za ubacivanje lima u mašinu. Ovaj deo programa prikazan je na slici ispod.



Slika 9. Prva linija PLC programa

Drugi korak: kada metalni lim dostigne krajnji položaj aktivira se prekidač CX. CX je povezan na X3 ulaz. Ovaj ulaz aktivira izlaz Y3 koji se odnosi na DY ventil i "D" cilindar koji priteže metal u mašini i deaktivira izlaz teže2, cilindar "C" se vraća u početni položaj, slika 10.

Slika 10. Programska linija koja obezbeđuje stezanje lima.

Sledeća linija programa je tajmer T0 koji se aktivira ulazom X3. Ovaj tajmer ima kašnjenje od 2s, čime se osigurava da je cilindar C došao u početni položaj. Ova linija je prikazana na slici 11.

Slika 11. PLC tajmerska rutina.

Kada T0 odbroji 2s, izlaz Y0 se aktivira. Ovaj izlaz je povezan na AY ventil koji aktivira cilindar „A“. Programska linija je prikazana na slici 12.

Slika 12. Programska linija za aktivaciju cilindra A.

Peti korak: Kada cilindar A dostigne granični prekidač AX na ulazu X1, aktivira se izlaz Y2. Ovaj izlaz je povezan sa ventilom BY, koji aktivira cilindar „B“.

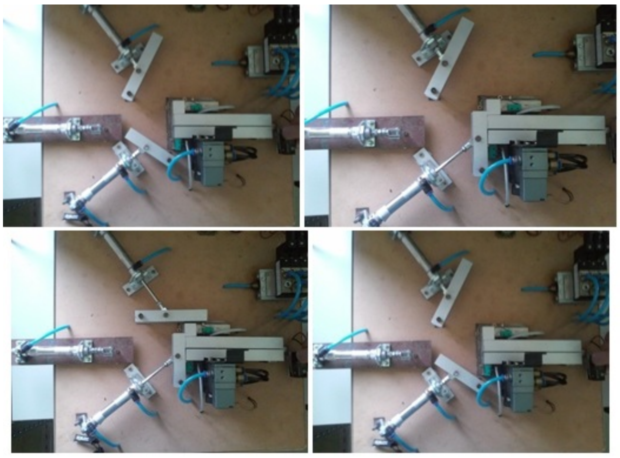
Slika 13. Linija programa koja aktivira cilindar B.

Nakon toga se aktivira krajnji prekidač BX. Povezan je sa X2 ulazom. U sledećoj programskoj liniji (slika 14.) ovaj ulaz se koristi za vraćanje cilindra „B“ u početni položaj, a nakon 2 sekunde tajmer T1 cilindar „A“ prelazi u početni položaj.

Slika 14. Vraćanje u početnu poziciju.

Za ponovno pokretanje sekvence mašine potrebno je pritisnuti taster T1.

Slike snimljene u laboratoriji pri radu postavke prikazani su na sledećoj slici. Slika sadrži četiri segmenta vezana za programske linije: prva slika povezana je sa programskom linijom prikazanom na slici 10, druga je povezana sa linijom prikazanom na slici 12, treća slika predstavlja izvršenje sa slike 13, a četvrta slika kada se sistem vrati u početni položaj, linija prikazana na slici 14, gledajući s leva na desno, od odozgo na dole.



Slika 14. Izvršavanje programa kroz programske linije..

6. ZAKLJUČAK

Poslednjih dvadeset godina inženjerstvo se drastično promenilo. Da bi se ispratili trendovi, promenjeno je i obrazovanje u ovoj oblasti. Računari postaju široko dostupni u svakodnevnom životu. To je prouzrokovalo brzi razvoj različitih softverskih rešenja za obrazovanje inženjera. Modelovanje i simulacija mogu značajno unaprediti proces učenja i podučavanja elektro-pneumatike. Ovaj rad predstavlja projektovanje, simulaciju i primenu obrazovnog seta sa elektro-pneumatskim sistemom upravljanja.

Ovaj sistem je napravljen od standardnih komponenata u pneumatici i elektro-pneumatici. Rađena je računarska simulacija. Ova simulacija pomaže studentima da razumeju kako sistem funkcioniše i kako da podese sistem da radi ispravno. Najvažnije prednosti ove računarske simulacije u obrazovanju su interaktivnost, podsticanje vizuelizacije kod studenata i poboljšanje njihovog procesa rešavanja problema. PLC je dodat na sistem, tako da studenti uče da ga programiraju i uključuju se i u ovaj deo inženjerstva. Primenom PLC-a može se zaključiti koje prednosti ima u poređenju sa klasičnim načinom realizacije sekvence elektro-mehaničkih i logičkih komponenata. PLC program smanjuje broj električnih veza u sistemu i sistem se lako može reprogramirati ako je potrebno.

Rad je napisan na osnovu iskustva sa nekoliko predmeta sa studijskog programa mehatronika. Studenti koji su pohađali ove kurseve pokazali su znatno bolje profesionalne rezultate na razgovorima za posao i dobili su mnogo bolje pozicije od onih koji nisu imali ove kurseve.

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Laboratory Electro-Pneumatic Motion Control Setup

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Studying the dynamic behaviour of objects or systems in response to conditions cannot always be easily or safely applied in real life. Computer simulations in engineering are very important as it solves real-world problems safely and efficiently. It provides an important method of analysis which is easily verified, communicated, and understood. Across industries and disciplines, simulation modelling provides valuable solutions by giving clear insights into complex systems. A system presented in this paper is a pneumatic sheet metal bending laboratory setup. An electro-pneumatic motion control of this system is modelled and simulated in FluidSim software. This system is also physically built using main pneumatic and electrical components with PLC. Described laboratory setup in this paper was used in the education of students and significant enchantment in the understanding of how similar systems work was noticed.

Keywords: Laboratory Setup; Design; Simulation; Programming; FluidSim

1. INTRODUCTION

Simulations can be defined as computationally correct representations of a situation which offer the user control over the outcome of the program. [1]

Computer simulation has an overwhelming potential for the enhancement of the teaching and learning of science concept. Computer simulations provide interactive, authentic and meaningful learning opportunities for learners because simulations facilitate the learning of abstract concepts since students would have the chance to make observations and get instant feedback. [2]

Another example of application of simulations is connecting and better understanding theory and practice. By using the computer simulations in teaching courses wherever it is applicable, students are developing engineering point of view of an encountered problem and can also get an opportunity to see how process behave in a real time simulation. [3]

Benefits of simulations are also in understanding the value and limitations of a numerical methods used in system, as well as possibility of optimizing the system solution as far as cost, time and energy is concerned.

Since compressed air became used as a substitute for physical labour, it is available in almost any industrial installation. Therefore, pneumatic cylinders and valves have become competitive in many applications such as motion control of materials, gripper devices, robotics, industrial processes, food processing, etc. That is why the study of the simulation and control models of these actuators has become a relevant teaching subject. [4] The control of pneumatic components using electrical impulses is known as electro-pneumatics.

Design of the laboratory setup control of an electro-pneumatic system for an industrial process of the sheet bending machine is presented in this paper.

The system is built using real industrial components and enables the implementation of practical knowledge and skills that are easily applicable in practice.

Simulation of the pneumatic system operation is realized in FluidSim software which is a comprehensive software for simulation of fluid control systems. FluidSim software helps students to analyse and solve problems with relevant knowledge and enhance their practical abilities. [5]

Programmable logic controller (PLC) has been added to the system. Program has been realized on this educational set to achieve required sequence.

2. STRUCTURE OF THE LABORATORY SETUP

Motion sequence control is a mandatory step by step process in which the following control is programmed by the previous step. In an electro-pneumatics control system, three major circuits must be identified: a pneumatic circuit, a control circuit (electric) and a power circuit. The control circuit and power circuit are electric. [6]

The design of the electro-pneumatic system for bending of metal sheets is shown in Fig. 1. Tools and equipment used for building this system are compressor, air treatment unit, pressure regulator, pipeline, educational set „Sheet metal bending", PLC controller and a computer with required software.

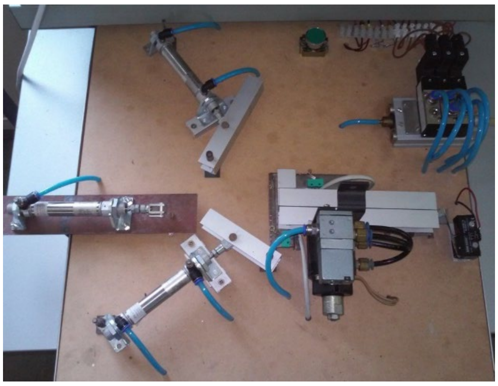

Figure 1. Electro-pneumatic system for sheet metal bending [3]

The basic function of a compressor is to convert the supplied mechanical energy into the energy of compressed air.

The main characteristics of the compressor are airflow rate, the amount of compressed air and the pressure achieved after compression. A reciprocating compressor with rectilinear piston movement, which is mostly used in today's practice, is used in this educational set. Compressed air and moisture increase the wear rate of surface and sealing and is reducing the efficiency and service life of pneumatic components. Also, unstable pressure has a negative impact on the operation of the complete system.

When speaking of air compressors, before entering the pneumatic devices, it is necessary for air to be treated adequately. Compressed air treatment is a process that dehumidifies, lubricate, cleans air and regulate its pressure. An air treatment group consists of a filter, a lubricator and a pressure regulator. An effective compressed air treatment system lowers the "dew point" of the air and takes out particles that may negatively harm the air compressor, such as dust and corrosion products, water, steam, compressor oil. A lubricator is used to inject oil in the form of a fine mist into the air stream. The role of the pressure regulator is to provide a stable desired operating pressure. The pressure regulator dampens the pressure oscillations due to the variable air consumption that occurs as a disturbance on the outlet side of the regulator and reduces the air pressure from the main line to the required value of the working pressure.

Main pneumatic and electrical components of a „Sheet metal bending" educational set are: single-acting and double-acting pneumatic actuating cylinders, solenoid impulse valves, pushbutton, limit switches and PC with software. Pneumatic linear motors - cylinders convert the energy of compressed air into mechanical work. In pneumatic systems, the cylinder is usually the executive element. They can be with one-way (single acting cylinder) or two-way (double acting cylinder) operating mode. Single acting cylinders have the working fluid acting on the piston only from one side of the piston, whereby the connecting rod is pulled out and perform the mechanical work. Return of the piston to its starting position is done either with a spring on the other side of the piston or by its weight. Double acting cylinders have the working fluid supplied from both sides of the piston so that the cylinder has a working stroke in both directions. A pneumatic distributor is used to control the double acting working cylinder.

Distributors are valves that pass, close and direct the flow of working fluid. Distributor type is determined by the number of connections, number of positions (states), activation method, return method and connection sizes. The label of distributor type corresponds to the number of connections and distribution positions. In the realization of described educational set, electromagnetic controlled air distributors type 5/3 and 3/2 were used. Type 3/2 means three ports and two positions: one port connects to the source of compressed air; second port serves as outlet and the third port connects to the cylinder.

The valve has two positions: filling or emptying the cylinder. The required valve size can be calculated once the cylinder and application properties are known.

By working on this educational setup, students get familiarized with the principles of operation of applied pneumatic components. They learn to design pneumatic systems, simulate their operation, and most importantly they learn to implement such a system using PLC programming software. [7]

As a presentation of this educational setup in operation, the process of sheet metal bending is used. This task consists of a several sequencing steps of bending a sheet metal to make a "J" profile. A complete sequence for the metal sheet bending task is shown in the Fig. 2.

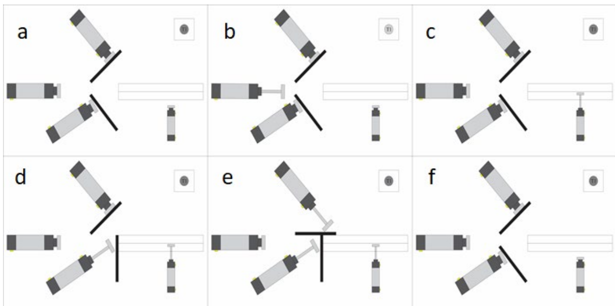

Figure 2. Sequencing of sheet metal bending operations [3]

The control sequence consists of the following steps: (a) Manually place the sheet metal in the form of a strip in the machine. The cycle starts by pressing the T1 pushbutton; (b) single acting cylinder C pushes the sheet metal strip until the position CX is reached; (c) Cylinder C then returns to the home position; (d) One-way cylinder D clamps the sheet metal into the tool; (e) Then the double acting cylinder A bends the strip until it reaches AX position, the two-way cylinder B then bends the sheet metal to the limit position BX; (f) At the end of the cycle, all cylinders return to the home position, and finished "J" profile sheet can be taken out.

3. DESIGN OF THE PNEUMATIC SYSTEM

Pneumatic system is made from two parts:

1. pneumatic
2. electrical.

Simulation of pneumatic power system is made in FESTO FluidSim software (Fig. 3). FluidSIM is a software customized for the modelling, simulation, and study of electro-pneumatic, electro-hydraulic, digital, and electronic circuits. All the listed functions can integrate easily, combining different media forms and sources of knowledge in an easily accessible manner. Software is intuitive for circuit making with full description of all components, standard component symbols and properties [8]. Pneumatic components are explained with textual descriptions, symbol, figures, and animations that illustrate working principles [9].

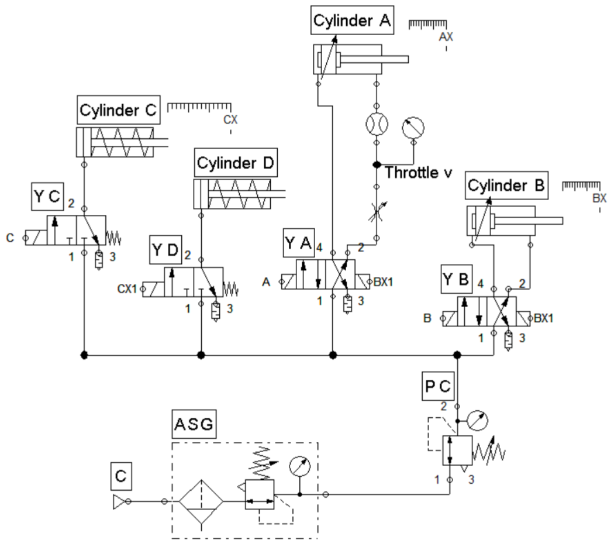

Figure 3. FluidSim schematic diagram of the pneumatic circuit [3]

Electrical circuit should be done in various ways. Every student must apply his logic by designing his own circuit diagram for the desired system to do the required sequence. This electrical design should be used in only in simulation, so students can use all electrical component they think they need, or in practice (in our example PLC circuit diagram). Electrical simulation schematic is shown on the Fig. 4.

Pressing the button (F9) simulation starts, while button T1 is used to start the sequence that is being simulated. This simulation helps students to see if their logic is working or not. After their logic is working in simulation, pneumatic and electrical schematics can be implemented on a real system (PLC program).

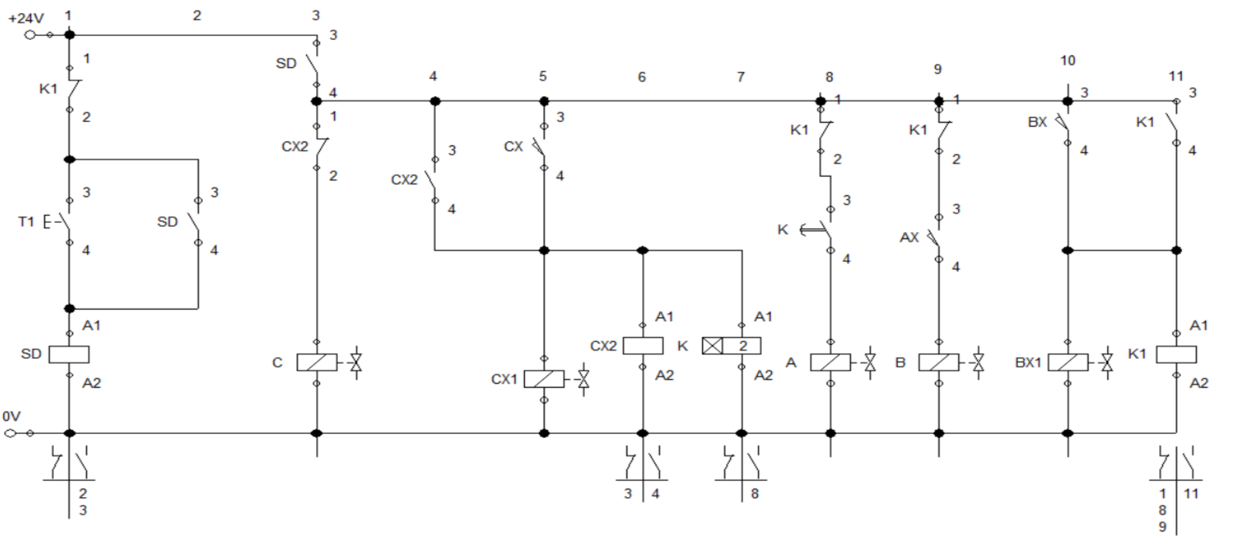

Figure 4. Electrical schematic of the system [3]

The component part of the EPM system is as shown in Table 1, for pneumatic and electrical circuit of the system. Each symbol can be parametrized as physical component in the system. Double-acting pneumatic actuating cylinder A (PCU-16-50-DD-A) has 50 mm maximum stroke, 16mm piston diameter and 5mm rod diameter [10].

Those parameters must be configured in cylinder configurator. Solenoid valves must be configured as cylinders. The parameters must be in accordance with the documentation for every valve in the system. Each component must be properly configured for the simulation to be done properly.

Table 1. Description part list for EPM system [3]

Number of items	Designation	Description
1	C	Compressed air supply
1	ASU	Air service unit, simplified representation
2	Cylinder A, B	double-acting actuating cylinders
2	Cylinder C, D	single-acting actuating cylinders
2	AY, BY	4/2-way valves
2	CY, DY	3/2 -way valves
1	T1	Pushbutton
3	AX, BX, CX	Limit switch
1		Electrical connection 24V
1		Electrical connection 0V
1	SD	Self-holding relay
8	C, CX1, A, B BX1	Valve solenoid
2	K, K1	Relay
1	K	Time delay relay
1	PLC	PLC Direct Logic 05

4. SETUP SIMULATION

FluidSim software for simulation of the system is wary easy access modelling and user-friendly options. Different computer simulations and experimental process ware carried out by means of the developed model shown in Fig. 3. The following results were obtained to ascertain the workability of the system. Beside logic simulation, the program FluidSim can also simulate states of the system on the time axis. Those states can be different parameters: speed and position of cylinder, pressure and flow rate on the desired component. In this paper cylinder acting with flow change in his one input is simulated. Flow has been variated from 1% to 20% in six steps (1%, 2%, 3%, 5%, 10%, 20%). Graph with position and velocity of desired cylinder A and B, as well as graph of pressure and flow on throttle valve are given in the Fig. 7.

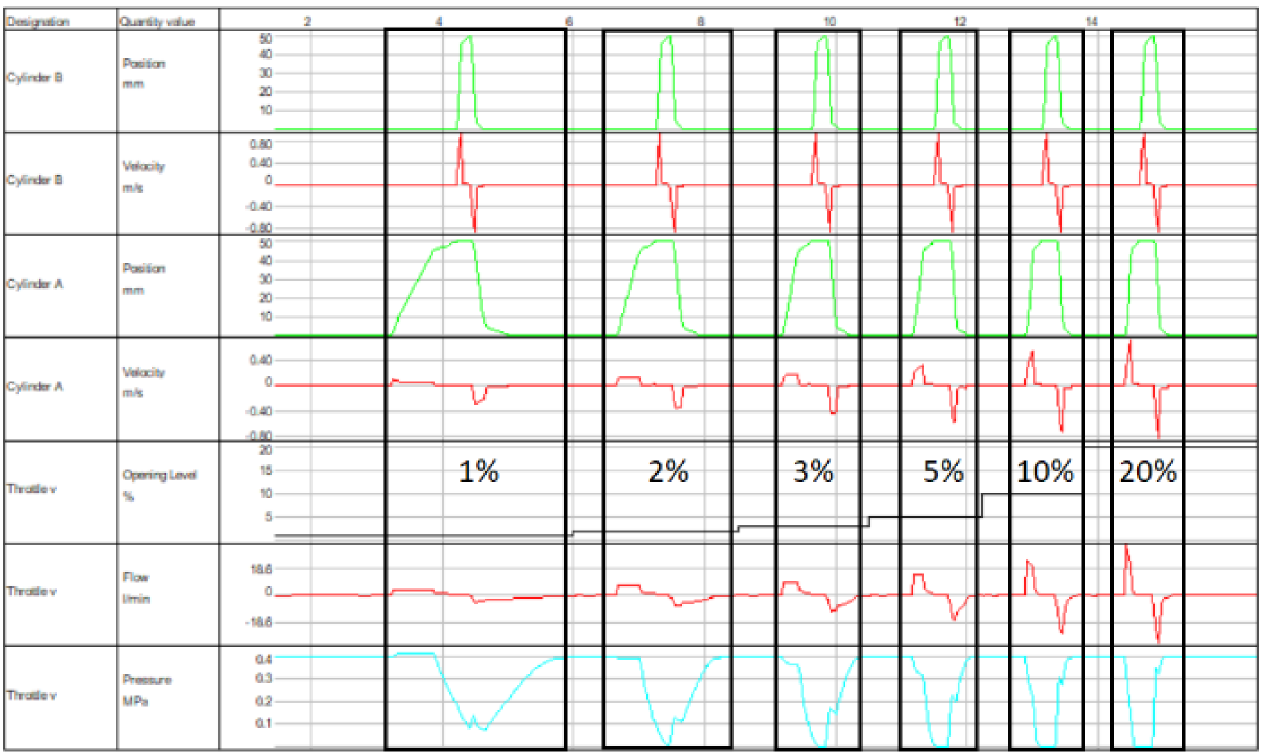

Figure 7. The simulation diagram result of dependence of position and velocity on different throttle valve openings for cylinders A and B [3]

This graph contains acting cylinder speed is proportional with flow through it. As flow is increasing the acting cylinder speed is increasing, and it takes lower amount of time to react. Cylinder A has flow regulation on one input, but it impacts on both inputs as graph shows. Throttle valve on one side reduces the flow change in the cylinder on both sides (extraction and retraction). With this type of simulation, cylinder speed can be adjusted to the value that has to be achieved on a real system. Acting speed of the cylinder A in analysed system is important because if it is not tuned well, it can cause collision with the other cylinder or mechanical part in the system.

5. PLC PROGRAM

Program logic controller (PLC) is hardware that replaces complex electrical circuits. It is easy to change logic and adjust system to work properly. Electrical schematic designed with PLC is shown on Fig. 8. It is immediately apparent that this schematic is far simpler than the previous one shown on Fig. 4.

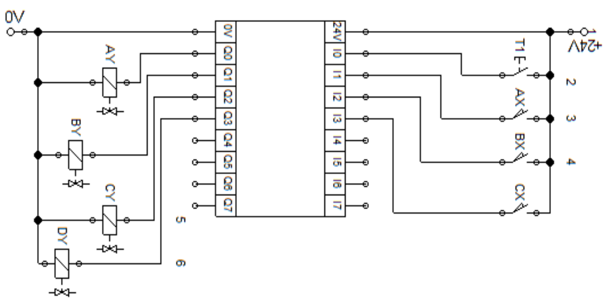

Figure 8. Electrical schematic with PLC hardware.

PLC program contains all logic in software that has to been made in schematic shown on Fig. 4. Program blocks are shown below.

Push button T1 is connected on X0 input. This input is programmed to activate output Y2 which is connected on CY valve which activate cylinder "C" to push the metal sheet in machine. This program sequence is shown in figure below.

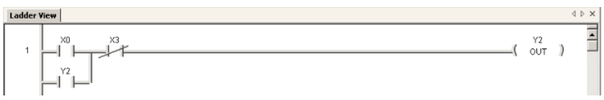

Figure 9. First line of PLC program

Second step: when metal sheet reaches its final position limit switch CX has been activated. CX is connected on X3 input. This input activates Y3 output which relates to DY valve and "D" cylinder which clamps metal in machine and deactivate output Y2, cylinder "C" returns to its home position, Fig. 10.

Figure 10. Program line which provides clamping of metal sheet.

Next program line is timer T0 with is activated with input X3. This timer has 2s delay with ensures that cylinder C has been returned in home position. This line is shown on Fig. 11.

Figure 11. PLC timer operation.

When T0 count down 2s output Y0 has been enabled. This output is connected on AY valve which activates "A" cylinder. Program line is shown in Fig. 12.

Figure 12. A cylinder activation program line.

Step five: When cylinder A reaches limit switch AX on input X1 the output Y2 is activated. This output is connected to valve BY, which activates "B" cylinder.

Figure 13. B cylinder activation program line.

After this the BX limit switch has been activated. It is connected to X2 input. In following program line (Fig. 14.) this input is used to return cylinder "B" to his home position, and after 2s timer T1 cylinder "A" goes to his home position.

Figure 14. Returning to home position.

After this program returns to first line, push button T1 must be pressed to start sequence again. Real footage of the laboratory setup in action has been shown in following figure. It contains three segments related to program lines: first figure is related to program line presented in Fig. 10, second is related to line shown in Fig. 12, third figure present the Fig. 13 execution, and forth figure present returning to home position, line shown on Fig. 14 respectively from left to right, from top to bottom.

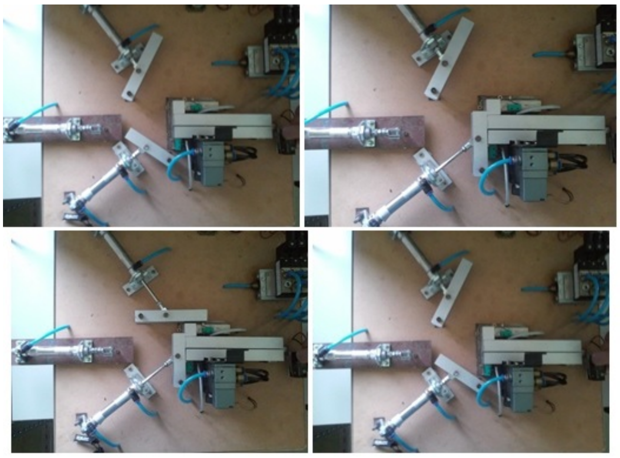

Figure 14. Execution the PLC program through the program lines.

6. CONCLUSION

Past twenty years in engineering has drastically changed. To stay in touch with it, education in this filed was changed. Computers become widely available in everyday life. This has cause rapid development of various of software solution for education an engineering. Modelling and simulation can significantly boost the learning and teaching process of electro-pneumatics. This paper represents the design, simulation and implementation of an educational set for electro-pneumatic motion control system.

This system has been made of main components in pneumatics an electro pneumatics. Computer simulation has been done. This simulation helps students to understand how the system works and how to adjust the system to work properly. The most important advantages of these computer simulation in education are interactive feature, fostering student's visualization, and enhancing their problem-solving process. PLC program has been made on this system, so students learn to program it and get involved in this part of engineering. They can conclude what advantages has PLC in regard of classical electrical connection with electromechanical and logic components. PLC program reduces number of electrical connections in system and system can be easily reprogramed if needed.

The paper is written based on experience with several subjects in mechatronics. Students who took these courses showed significantly better professional results in job interviews and got much better positions than those who did not have these courses.

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