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DEVELOPMENT OF CONTROL SYSTEM BASED ON LABVIEW HYDRAULIC PNEUMATIC INTEGRATED LABORATORY

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Abstract: The liquid-pneumatic transmission method is a transmission method commonly used in today's electromechanical transmission facilities. It has the advantages of stable transmission, large transmission power, etc. With the development of science and technology, it plays an outstanding role in numerical control, engineering machinery, and automated production lines. The basic theoretical research of liquid-pneumatic transmission, the performance analysis and inspection of liquid-pressure products, and the operation status of testing equipment are all inseparable from the testing of various parameters of the liquid-pneumatic system. The hydraulic pressure test is the basis for realizing hydraulic automatic control. The feedback of signals such as pressure, speed and flow is the basis for calculating the control output. This article mainly introduces the experimental projects of multiple liquid-air element loops and the development of the test bench control platform based on LabVIEW graphical programming software. The test stand can complete the data acquisition and analysis and real-time monitoring of the hydraulic pump, proportional relief valve and proportional directional valve, and achieve real-time monitoring of various parameters in the experimental oil circuit.

Keywords: Liquid-Pressure Test， Data Acquisition, LabVIEW, PLC, Communication, hydraulic

I. INTRODUCTION

Hydraulic transmission is a kind of transmission method that uses hydraulic oil as working medium (generally composed of an emulsion, a variety of mineral oils, and synthetic oil) and uses liquid pressure energy to transmit energy and signal transmission in the sealed circuit. (Price & Beasley, 1963) (Korn, 1969). Hydraulic transmission plays a very important role in modern new technology Vasiliu et al. (2012). The hydraulic basic circuit constitutes the most basic structural and functional unit of the hydraulic system. A complete hydraulic drive system consists of the following components: (1) Power elements (2) Actuators (3) The control element (4) Auxiliary components

Pneumatic transmission uses compressed air as the working medium for transmitting power and control signals, providing driving force and torque, and controlling the position, speed, force, and torque of the actuator, and carrying out energy transmission or signal transmission engineering technologies (Gill, Kumar, and Kumar, 2015). Pneumatic circuits are used to drive mechanical devices used for a variety of purposes. The three most important controls are: the size of the force, the direction of movement, and the speed of movement. Various types of cylinders that are connected to the production device are controlled by the pressure control valve, the directional control valve, and the flow control valve. The air compressor generates compressed air with a certain pressure and flow rate, and its air intake is equipped with an air filter.

Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) is a platform and development environment for a visual programming language from National Instruments. (Elliot et al 2007) The graphical language is named "G". Originally released for the Apple Macintosh in 1986, LabVIEW is commonly used for data acquisition, instrument control, and industrial automation on a variety of platforms including MS Windows, various flavors of UNIX, Linux, and Mac OS X. The code files have the extension ".vi", which is an abbreviation for "Virtual Instrument". LabVIEW offers lots of additional Add-Ons and Toolkits.

The programming language used in LabVIEW, also referred to as G, is a dataflow programming language. Execution is determined by the structure of a graphical block diagram (the LV-source code) on which the programmer connects different function-nodes by drawing wires. These wires propagate variables and any node can execute as soon as all its input data become available. Since this might be the case for multiple nodes simultaneously, G is inherently capable of parallel execution. Multi-processing and multithreading hardware is automatically exploited by the built-in scheduler, which multiplexes multiple OS threads over the nodes ready for execution.

Lab-VIEW programs/subroutines are called virtual instruments (VIs). Each VI has three components: a block diagram, a front panel, and a connector panel (Dhiviyalakshmi et al. 2013). Controls and indicators on the front panel allow an operator to input data into or extract data from a running virtual instrument. However, the front panel can also serve as a programmatic interface. Thus a virtual instrument can either be run as a program, with the front panel serving as a user interface, or, when dropped as a node onto the block diagram, the front panel defines the inputs and outputs for the given node through the connector pane. This implies each VI can be easily tested before being embedded as a subroutine into a larger program.

Hydraulic transmission is a transmission method that uses hydraulic oil as a transmission medium and uses hydraulic energy to transmit energy and signals in a sealed circuit. It is called a fluid drive with pneumatic transmission. Hydraulic transmission has a wide range of applications in the field of civil aviation. It is mainly applied in the following five areas: landing gear systems, hydraulic boosters, flaps and spoilers for retracting, wheel brakes, ground steering, and thus can be seen Hydraulic transmission involves almost every part of civil aviation aircraft (Johri, and Zoran 2010).

II. MONITORING AND CONTROL MODULE CONSOLE DESIGN

The measurement and control system consists of the power unit's electrical control cabinet and the measurement and control operation platform. The electric control cabinet can precisely control each motor and heating device. The monitoring and control operation center platform is mainly composed of a signal conditioning card, a PCI-9111 data acquisition card, an industrial control computer, a display, a signal output card, and a PLC. The measurement and control system mainly controls the control of the data acquisition and control system (Figure 1).

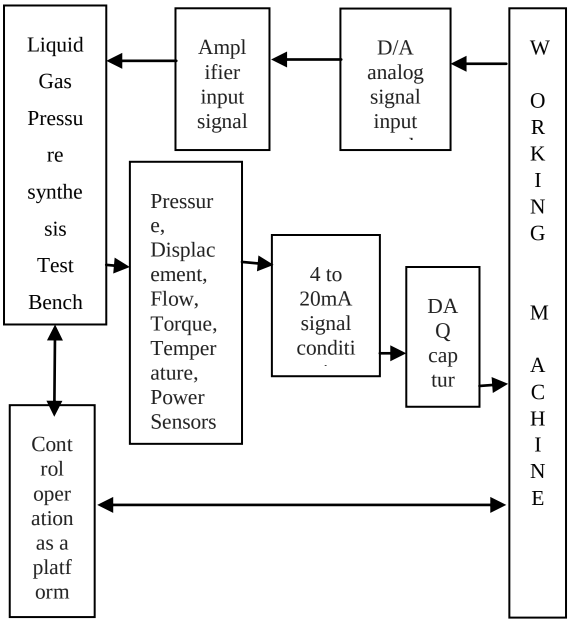

Figure 1: Experimental bench structures

At the same time, the liquid and pneumatic components of the laboratory bench can be controlled by the G code written by LabVIEW.

Electronic Control System Design

Because the safety conditions and control conditions of the liquid-gas comprehensive test bench are very important, designing the electronic control system needs to ensure the accuracy, economy, and rapidity of the system, as well as the safety of the system (Zuo et al 2012). The electronic control system consists of a working indicator, a tank air cooler and two three-phase asynchronous motors. The pump power is 1.5kW and the variable pump power is 2.2kW. The motor is directly connected to the power supply through the wire, so the starting current that starts directly will increase, causing the motor to be damaged. Therefore, the series resistor and the voltage start are used. The entire bench can be equipped with two motors, so no self-locking is required between the two motors (see Figure 2). The two motors can work independently.

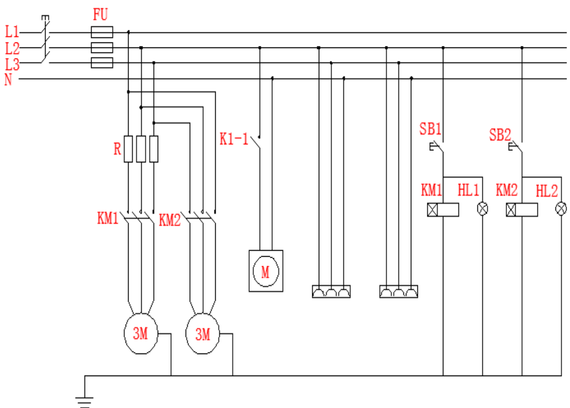

Figure 2: Experimental Station Motor Control Schematic

Data Acquisition Card Control Design

Selection of PCI-9111 Data Acquisition Card

The selection of a data acquisition card is based on its maximum sampling rate, acquisition accuracy, interface type of the data bus, software development platform, resolution, channel number, and software program drivers. The liquid-pressure test bed is a ADLink-PCI-9111 data acquisition card developed by Taiwan's ADLINK, which is based on a 32-bit PCI bus data acquisition card. The main features are: software triggering, timer triggering, and external pulses. Trigger, support 100kHz A/D sampling frequency, support 256 channels of autonomous scan selection, 12-resolution analog input.

III. LabVIEW Computer Programming and Debugging

LabVIEW upper computer controls

Completion of the LabVIEW program and PLC program, according to the steps in the previous part to complete the link between the two, then, open the PLC program, download the program to the S7-200 PLC hardware, and the PLC is in the RUN state, start the debugger, open the total Power supply, then run the LabVIEW program, click the switch button, and then click on the travel switch 1 (Figure 3). At this time, the electromagnet 1 lights, corresponding to the movement of the piston rod of the experimental bench; close the limit switch 1, click the limit switch 2, the electromagnet 2 lights; close the stroke Switch 2, click on the travel switch 3, the electromagnet 3 is on, and the piston rod makes the corresponding movement.

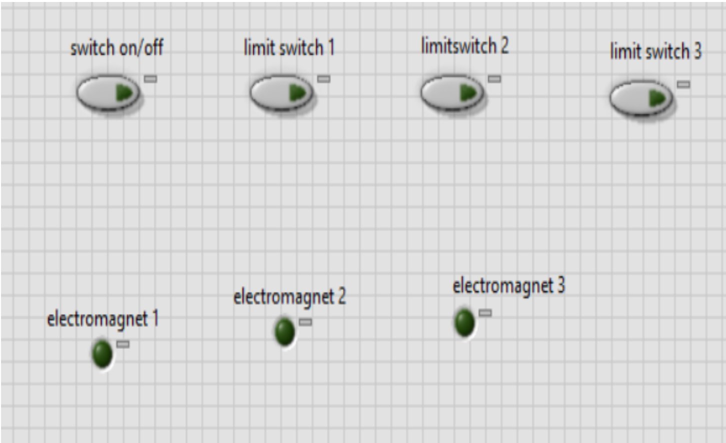

Figure 3: upper computer control interface

LabView PC control PLC

After the program is written, download the program to the PLC hardware, put the PLC in RUN mode, run the PLC program, connect the oil circuit of the experimental platform, open the experimental power supply after confirming correctly, press the SB1, the electromagnet 1 will become brighter, the piston rod When moving to the side and touching the sensor switch 2, the electromagnet 2 will become brighter and the electromagnet 1 will become darker. In the process of returning, it will approach the proximity switch again, the hydraulic cylinder will change direction and repeat the movement; click the stop button, all the lights are dimmed and the piston rod stops moving.

Data collection page settings

This program is mainly to set the sensor, the parameters are: sensor channel, data range, signal voltage range, etc. The sensor collected signal from the signal sensor module, including: displacement, flow, pressure, power, torque and other acquisitions. Set the scope of acquisition data changes and collection channels, add the while loop, delay function, global variables, Boolean controls, and data binding functions in LabView. After the setup is complete, click Finish. At this time, all sensors will collect data once in 0.1s and use different types of data to generate cluster data through functions, and then write global variables.

Control acquisition system programming

This program can monitor and record the data. Select the appropriate options before starting. Click Start to read the signal filtering, sampling frequency, and save position, even if the abscissa is selected. The corresponding analog quantity passes the sensor's parameter according to the corresponding rule to convert into the digital quantity, simultaneously may merge the different digital signal, through the character string data conversion, saves in the table form for the '.txt' form.

Data Analysis Program Design

This program mainly completes the analysis of the collected data and generates the corresponding time-varying curves. Click to read the data, select the data generated by the data control program, read the experiment list, select the object variable, and set it to Y. Axis variables, X-axis variable settings default to the time t, generate curves, generate the corresponding XY image in the waveform control (Figure 4).

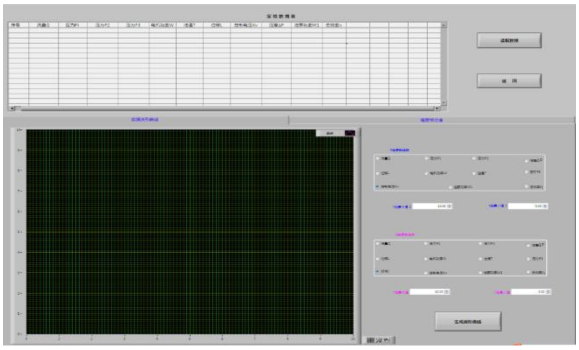

Figure 4: Data Analysis Interface

Lab Debugger

Connect the hydraulic proportional commutation control dynamic and static circuit according to the experimental principle diagram. After the connection is successful, the relief valve will be opened, the variable pump will be opened, the PLC program module will be uploaded, the PLC will be in the RUN state, and the LabView and the PLC will communicate via OPC. Click the start button, the piston rod of the hydraulic cylinder extends and retracts; open the collection system, and set the parameters, enter the collection interface, and adjust the mode of the electrical equipment measurement and control to PC in the collection. Save the collected data. Open the acquired data in the data program and generate the corresponding curve. Click the stop button to close the variable pump.

PCI-9111 Data Acquisition Card Wiring

The PCI-9111 is a 16-channel, 100KS/S, cost-effective multi-function DAQ capture card featuring a flexible analog input configuration. Each A/D input channel incorporates an RC filter to attenuate or filter the input signal. The PCI-9111 Series provides a bipolar input with five programmable input ranges for the analog input. The PCI-9111 series also supports automatic analog input scanning. The PCI-9111DG provides 12-bit A/D resolution, while the PCI-9111HR offers 16-bit A/D resolution. The ADLINK PCI-9111 series is also ideal for cost-effective and reliable data acquisition. When sampling, convert 250Ω sampling resistor into 1～5V voltage signal. The sensor output is 4～20mA standard current signal. Figure 7, below shows schematic representation of Signal Acquisition module.

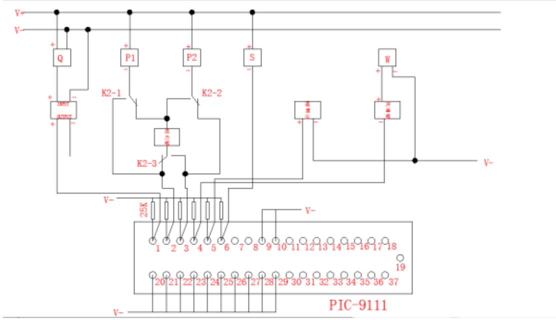

Figure 5: Signal Acquisition Schematic

1) CH0: Capture card 1 pin connection flow signal (through flow meter);

2) AICH1: Acquisition card 2-pin connection pressure P1 signal;

3) AICH2: Acquisition card 3-pin connection pressure P2 signal;

4) AICH3: acquisition card 4-pin connection power W signal;

5) AICH4: acquisition card 5-pin connection temperature T signal;

6) AICH5: Acquisition card 6-pin connection displacement X signal;

7) AICH6: acquisition card 7-pin connection torque N signal (standby);

8) AICH7: 8-pin standby card;

9) AICH19 ~ AICH26: Eight channels are connected to the module ground (9, 10, 28, 29 pins);

10) AICH29: 30-pin capture card connected to the amplifier control terminal (molded ground and molded ground).

Liquid-air pressure circuit design and PLC debugging

In the liquid-air circuit, select several typical circuits:

(1) Two-stage speed control loop

(2) Differential loop

(3) Dynamic and static experimental circuit of hydraulic proportional directional valve control system

(4) Using a pneumatic sensor position control loop

(5) Two-cylinder sequential motion control circuit

Since many complex liquid-air circuits are also composed of these simple circuits, these circuits are representative and can also be helpful for learning and understanding other circuits.

Liquid-pneumatic system design

(1) Two-stage speed control loop

Working principle: Because the commutation of the three-position four-way reversing valve can be controlled by the limit switch, therefore, when the solenoid valve is energized and the system does not have the back pressure, it can pass the speed control valve and the two-position three-way electromagnetic reversing valve (Figure 6). The speed regulation of the system, at this moment the speed control valve in the system cannot function;

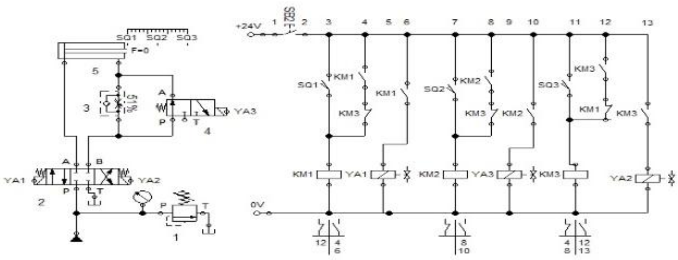

Figure 6: Two-stage speed control loop

(2) Differential loop

Working principle: After pressing the SB1 switch, the circuit is turned on, the YA1 is powered, the three-position four-way electromagnetic reversing valve works in the left position, and the piston rod of the hydraulic cylinder moves to the right; when the YA3 is powered, two The three-way electromagnetic reversing valve is working in the left position. The hydraulic oil enters the right hydraulic cylinder to form a differential circuit (Figure 7). The piston rod moves to the left. At this time, the proximity switch will sense the signal and move the two-position three-way electromagnetic reversing valve in right position.

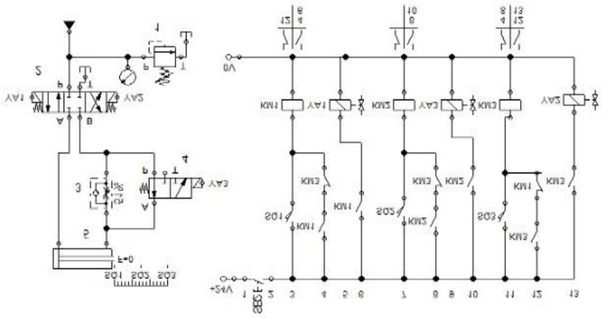

Figure 7: Differential Control Loop

(3)Static and dynamic tests of hydraulic proportional directional valve control system
Working principle: according to the circuit diagram after the lab bench is linked to a good oil circuit (Figure 8). The valve opening of the proportional directional valve can be adjusted by controlling the output voltage of the meditation program and the given button of the manual control amplifier.

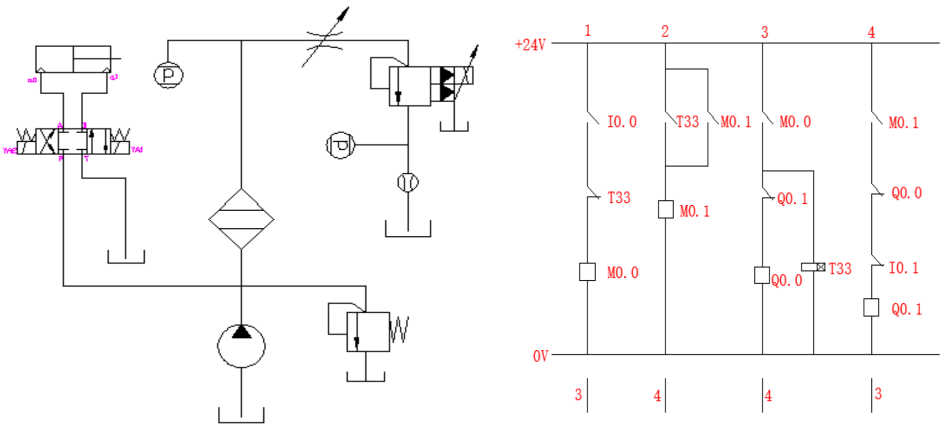

Figure 8: Measurement and control experiment of hydraulic proportional

(4) Pneumatic sensor position control loop

Working principle: The air compressor generates compressed air and enters the system. Two different air source processing devices form two kinds of pressure gas. After the manual control button is switched, the valve is switched to the two-position five-way electromagnetic reversing valve. The energized and de-energized electromagnet controls the intake and exhaust gases to achieve the extension and retraction of the double-acting cylinder (Figure 9). When the cylinder passes through the sensors in different positions, the sensors control the electromagnets YA3 and YA4 respectively to achieve the position control.

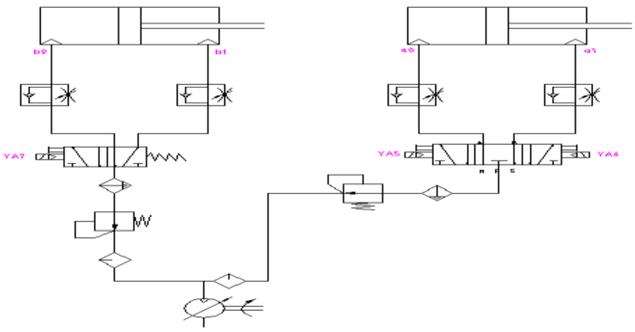

Figure 9 Pneumatic sensor control loop

(5) Double cylinder sequential action circuit

Working principle: The compressed air produced by the air compressor enters the system after being processed, firstly through a single electric control two-position three-way electromagnetic reversing valve and a pilot-operated three-position five-way electromagnetic reversing valve (Figure 10, Schematic representation). As the initial state of the cylinder piston rod is retracted, the energization of the electromagnets YA5 and YA6 controls the intake and exhaust gases to achieve the control of the cylinder 1, and the YA7 controls the cylinder 2. When the power is turned off, it is replaced due to the action of the spring force. The valve is reset and the piston rod of the 2 cylinder is retracted.

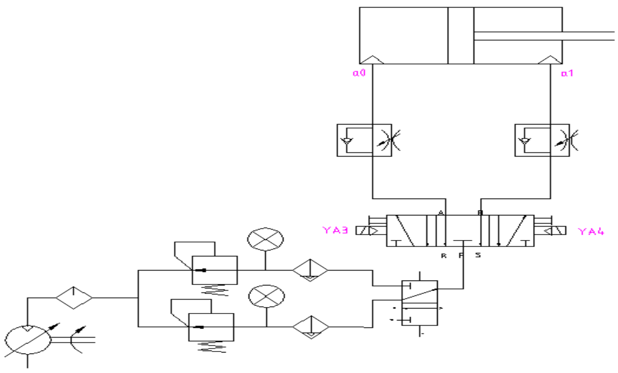

Figure 10: Double cylinder sequential action loop

4. PLC Control System Design Test

Two-stage speed control loop

Table 1: PLC Input and Output (I/O) Allocation

Input			Output		
Device name/function	Code number	Device number	Device name/function	Code number	Device number
Start up	SB2	I0.0	Electromagnet YA1		Q0.0
Reach out	SQ1	I0.1/ M0.0	Electromagnet YA2		Q0.1
Retract	SQ2	I0.2/ M0.1	Electromagnet YA3		Q0.2
	SQ3	I0.3/ M0.2			

PLC program ladder diagram

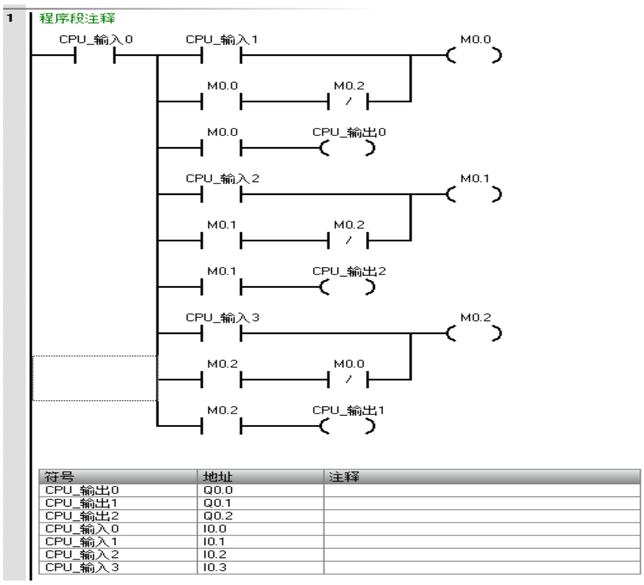

Figure 11: Ladder Diagram

(2) Debugger

The relief valve is fully opened, the working pressure is set, and the system maintains a certain pressure. At this time, the pumping station is started to drive the piston of the hydraulic cylinder. When the signal reaches the switch SQ1, the YA1 is powered to make the three-position four-way solenoid valve move in reversing direction, the piston rod is rapidly extended. At this time, the pressure regulating valve is pressurized and the pressure regulating valve is adjusted. The opening changes the speed of the piston rod and the piston rod decelerates. The YA2 is energized by the three-position four-way solenoid valve, the YA1 and YA3 lose power, and the piston rod quickly recovers. Re-sensing to SQ1 signal, action is re-executed.

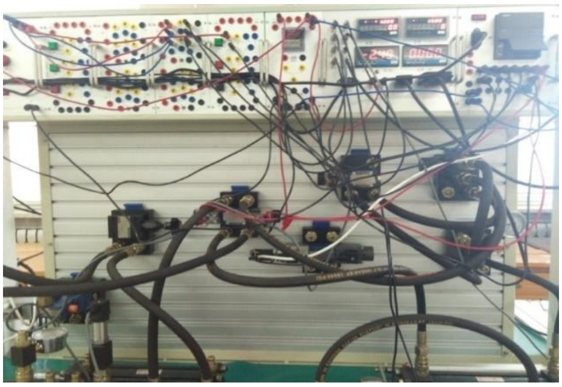

Figure 12: Circuit diagram of the lab circuit

The energizing and de-energizing of YA1, YA2 and YA3 electromagnets repeats moving the piston in the left. PLC ladder diagram (Figure 11) and circuit diagram (Figure 12) for the two-stage speed control loop shown above with input/output allocation (Table 1).

2. Differential circuit

Table 2: PLC Input and Output (I/O) Allocation Table

Input			Output		
Device name/function	Code number	Device number	Device name/function	Code number	Device number
Start up	SB1	I0.0	Electromagnet YA1		Q0.0
Reach out	SQ1	I0.1/M0.0	Electromagnet YA2		Q0.1
Retract	SQ2	I0.2/M0.1	Electromagnet YA3		Q0.2
	SQ3	I0.3/M0.2			

(1) PLC program ladder diagram

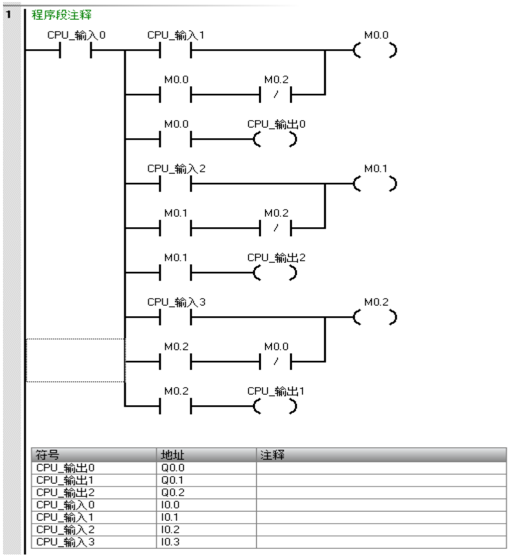

Figure 13: PLC ladder

(2) Debugger

Before starting the hydraulic pump station, the relief valve shall be fully opened. When the sensor switch SQ1 senses the signal, YA1 is energized, so that the three-position four-way solenoid reversing valve is reversed and the piston rod is extended. As the piston rod extends, Causes the SQ2 to sense the signal, YA3 gets electricity, and the two-position three-way electromagnetic reversing valve commutates. With the progress of the piston rod, the sensor switch SQ3 senses the signal, YA2 gets electricity, and the two-position three-way electromagnetic The reversing valve YA3 is de-energized, and the three-position four-way solenoid reversing valve is energized and the piston rod retracts.

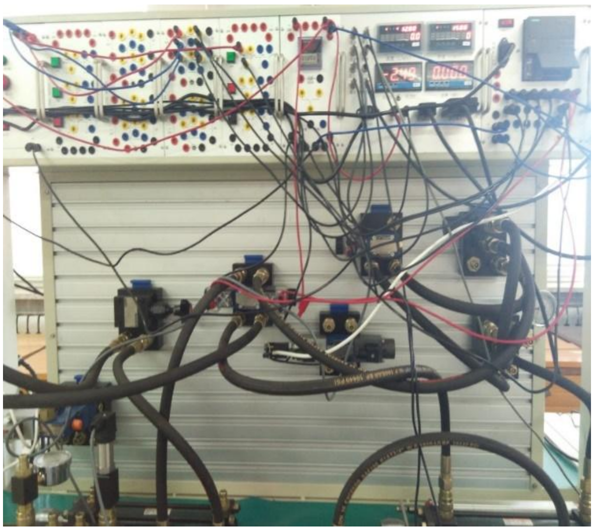

Figure 14: Circuit Wiring Diagram

PLC program Ladder (Figure 13) and Circuit diagram (see Figure 14) for Differential circuit is shown above.

3. Static and dynamic test circuit of hydraulic proportional directional valve control system

Table 3: PLC Input and Output (I/O) Allocation Table

Input			Output		
Device name/function	Device number	Code number	Device name/function	Device number	Code number
Startup delay	SB1	I0.0	Electromagnet YA1		Q0.0
a0	SQ1	I0.1	Electromagnet YA2		Q0.1

(1) PLC program ladder diagram

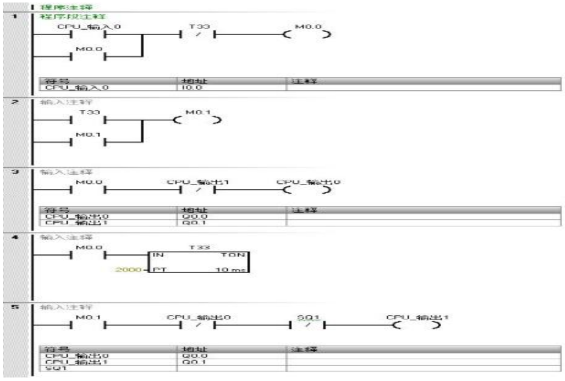

Figure 15: PLC ladder

(2) Program debugging

This loop is a program for data acquisition and analysis. Therefore, before the experiment, the parameters of the relevant sensors should be set. The flow of the curve is selected and the pressure is selected. The waveform of the signal is selected as a triangle wave, amplitude is 10V, frequency is 0.1Hz, and sampling period is set as 100ms. Select proportional directional valve as the monitoring and control object, "PID control" is empty, manually switch the switch to the directional valve option, set the path of the collected data, select the filter, start the variable pump, press the button SB1, the three-position four-way electromagnetic reversing valve is energized to drive the movement of the hydraulic cylinder.

After the piston rod extends for a certain period of time, the three-position four-way electromagnetic reversing valve YA2 is reversed, and the piston rod moves in the reverse direction when it comes into contact with the proximity switch. After a0, due to loss of power piston stops. Throughout the entire process, open the hydraulically acquired LabView program for data acquisition, and finally read the acquired data into the experiment table to generate curves.Figures 15 and 16 show the various components of the proportional directional control system setup along with device input/output values in table 3.

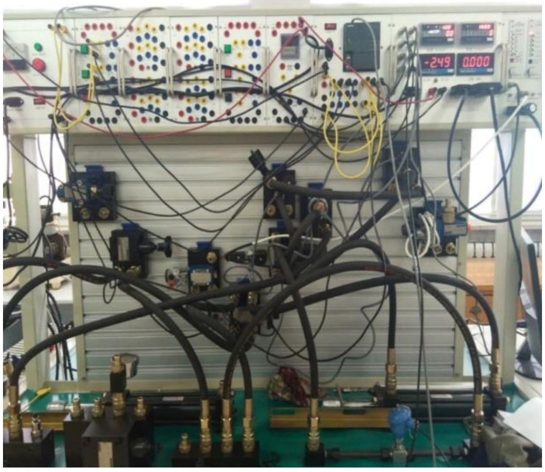

Figure 16: Experimental circuit wiring diagram

4. Start sensor for position control loop

Table 4: PLC Input and Output (I/O) Allocation Table

Input			Output		
Device name/function	Code number	Device number	Device name/function	Code number	Device number
Stop	SB3	I0.2/M0.3	Electromagnet YA3		Q0.2
Reach out	SB4	I0.3/M0.4	Electromagnet YA4		Q0.3
Retract	SB5	I0.4/M0.5			
Position sensor a0	BG2	I1.4			
Position sensor a1	BG3	I1.5			

Loop debugging

After the circuit is connected, press the button, the three-position four-way solenoid reversing valve is energized, and the right position works. At this time, the piston rod of the cylinder moves to the right, and when the two-position three-way electromagnetic reversing valve is powered to the right position, when the piston rod touches the sensor switch, the sensor switch signal, the two-position three-way electromagnetic reversing valve moves to left, the system repeats the process.

Figure 17 shows the pneumatic circuitry for the position control loop and Table 4 shows the device I/O allocation table.

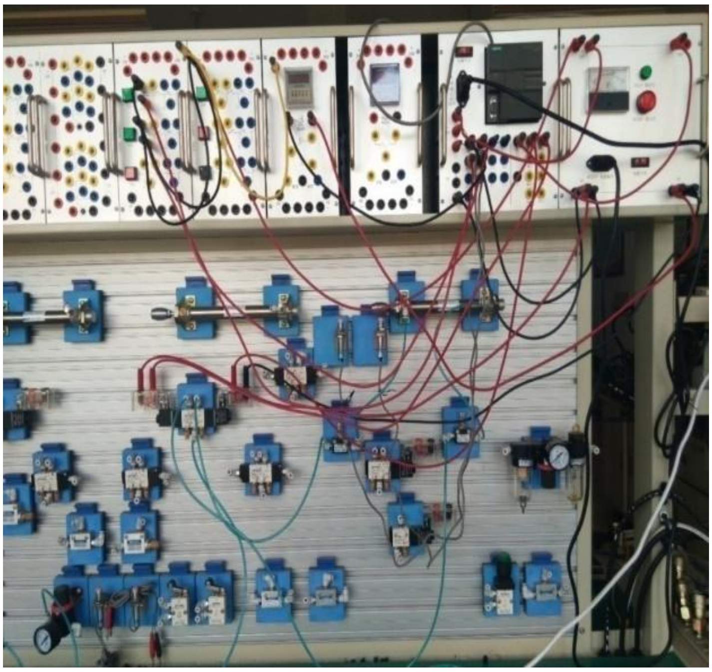

Figure 17: Pneumatic circuit wiring diagram

5. Two-cylinder sequential motion control circuit

Table 5: PLC Input and Output (I/O) Allocation Table

Input			Output		
Device name/function	Code number	Device number	Device name/function	Code number	Device number
Stop	SB6	I0.5/M0.6	Electromagnet YA5		Q0.4
Start up	SB7	I0.6/M0.7	Electromagnet YA6		Q0.5
Limit switch a0	BG0	I1.2	Electromagnet YA7		Q0.6
Limit switch a1	BG1	I1.3			
Limit switch b0	BG2	I1.4			
Limit switch b1	BG3	I1.5			

Program debugging

After the power is turned on, the air generated by the air compressor enters the system after being processed. First, it passes through a single electronically controlled two-position and five-way electromagnetic reversing valve. At the same time, it passes through a pilot-operated double-controlled three-position and five-way electromagnetic reversing valve. At the beginning, the piston rod is in a retracted state. The electromagnets YA5 and YA6 are energized to control the movement of the cylinder 1 in the direction of entering and exiting the air. The cylinder 2 is controlled by the electromagnet YA7. When the power is lost, the directional valve is reset due to the action of the spring. The piston 2 of the cylinder 2 is controlled to move.

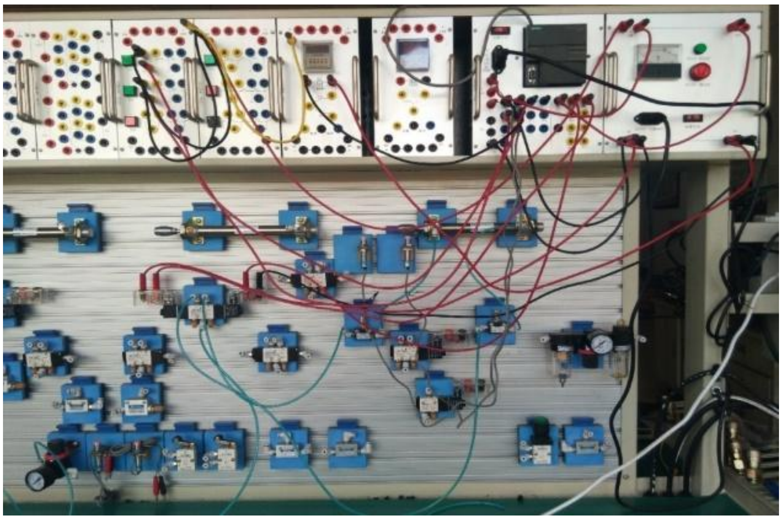

Figure 18: Pneumatic Circuit Connection Diagram

Figure 18 shows the pneumatic circuit connection for the two-cylinder sequential motion control and Table 5 depicts the various I/O allocation values.

Analysis in Automation studio PLC and Pneumatic

PLC Ladder Logic program for an electro-pneumatic circuit having 2 double acting cylinders and proximity sensors (Figure 19, 20 Logic diagram).

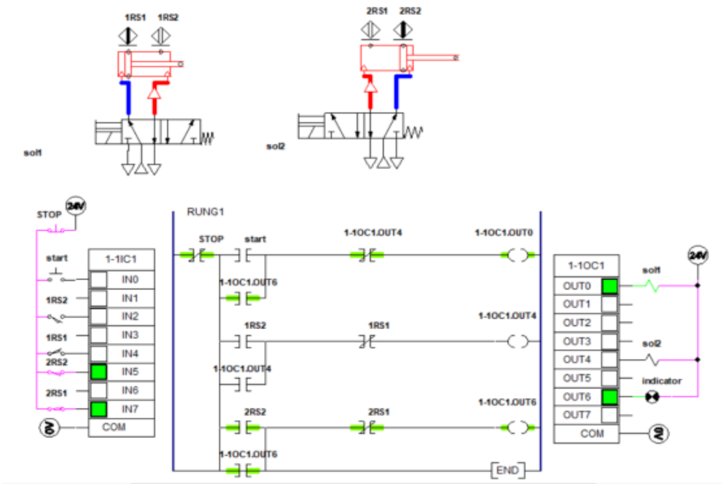

Figure 19: PLC Ladder Logic Program for pneumatic circuit

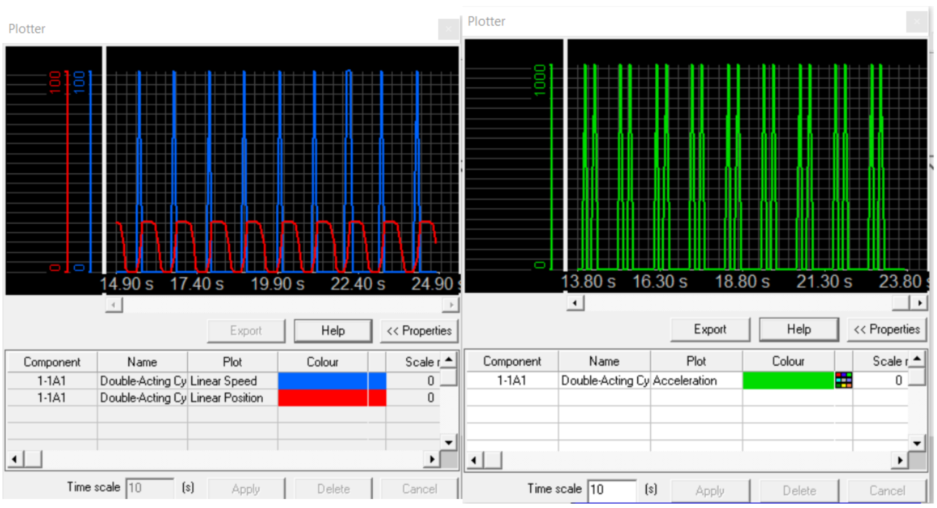

Figure 20: Acceleration and Linear speed of the Double-Acting Cylinder

IV. CONCLUSION

While defining hydraulic and pneumatic experiment setup in the laboratory test bench using the LabVIEW and PLC to study the working model of the actual device as well as the various valves involved in the functioning of the components in unison for the proper working of the machine. The landing gear system of the airplane is taken into account here and opening and closing of the landing gear along with opening and closing of door is studied in the laboratory. Time shift, acceleration, energization and de-energization of the electromagnets, valves and other components along with LabVIEW is understood. How retraction and movement of the reversing valves control the cylinders and piston movement is keenly studied through the laboratory experiment. Laboratory models help us in understanding the working of various components of an actual hydraulic machinery, and how alteration in data can affect proper functioning of the device.

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