An Automated Hydraulic Position Control System: Structure and Performance Analysis

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Abstract

Hydraulic systems are widely used in industry, since they can produce large torques, high-speed responses with fast motions and speed reversals. Automatic control of hydraulic systems has evolved into an increasingly superior alternative for many industrial applications. Advances in hydraulic hardware and electronics have combined to make the design and implementation of these systems more intuitive, reliable, cost effective, repeatable, and user friendly. Controlling the position of a cylinder is one of the more demanding hydraulic motion control applications. The project illustrated in the paper is a study of automated position control of a hydraulic cylinder through a Parker Compax3F fluid controller. This paper introduces the hardware components, structure, programming, configuration, and performance analysis of this automated hydraulic position control system.

Introduction

Automatic control of hydraulic systems has evolved into an increasingly superior alternative for many industrial applications. Controlling the position of a hydraulic cylinder is one of the more demanding motion control applications. The project described in this paper demonstrates the design, structure, development, and performance analysis of an automated hydraulic position control system.

The automated hydraulic position control system is designed to control the linear motion position of a hydraulic cylinder through a touch screen HMI (human-machine interface) and then establish the online remote access to the HMI. The major components of the system include a Parker 3L hydraulic cylinder, a position sensor, a DF Plus electrohydraulic servo valve, a PID controller, a Compax3F fluid controller, a touch screen HMI display, and a H-Pack hydraulic power supply. The control method applied is a traditional PID (proportional, integral, and derivative) control. As with most classical approaches for positioning hydraulic cylinders, the system does not give satisfactory performance due to a major dead zone problem. In this study, the system performance will be compensated through hardware configuration and CODESYS programming on the controller. Performance analysis will verify the resulting performance improvement.

System Overview

The hydraulic position control system consists of a hydraulic cylinder, a proportional valve, a position sensor, a fluid controller, and an HMI touch screen. Table I lists the specifications of these major hardware components.

Table 1. List of hardware components.

Part Name	Component Type	Part Number
Compax3F	Hydraulics controller	C3F001D2F12 I11 T30 M00
DF Plus Valve	Proportional directional control valve	D1FPE50FB9NB00 20
Parker 3L Cylinder	Hydraulic cylinder	01.50 F3LLUS23A 12.000
Parker H-Pak	Hydraulic power supply	H1B2 7T10P0X13909/13
Parker HMI	HMI display	XPR06VT-2P3

The system layout is illustrated in Figure 1.

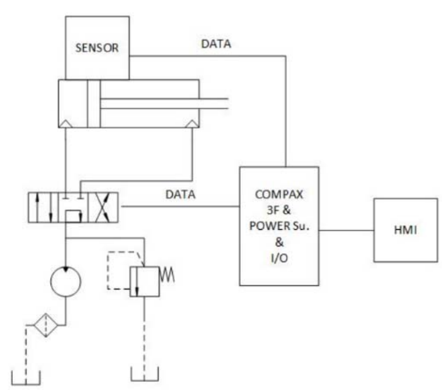

Figure 1. System layout and major components.

Pictures of the cylinder with position motion and the proportional valve are shown in Figures 2 and 3.

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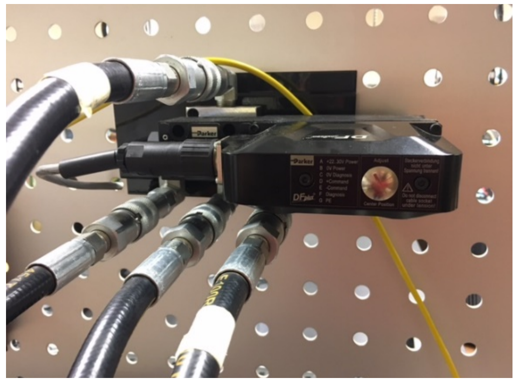


Figure 2. The DF Plus proportional valve.

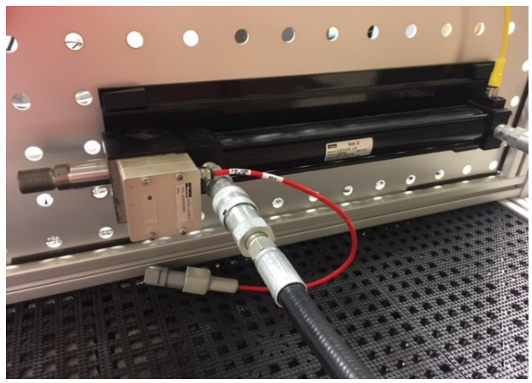


Figure 3. The linear cylinder with the position sensor.

The system uses Parker's Compax3F fluid controller as the main controller. Compax3F is a servo drive for position, velocity, force/pressure control of electrohydraulic systems. This controller is a programmable motion control device based on IEC61131, an international electrotechnical commission standard for programmable controllers. Compax3F is programmed by CODESYS, an IEC61131-based program development platform. The DF Plus Valve from Parker is used as proportional directional control valve that uses DC signals ranging from -10v to +10v to implement flow control on the motion of the hydraulic cylinder. A linear variable differential transformer (LVDT) is used to validate the cylinder position and provide feedback to the controller to improve the accuracy and repeatability. The LVDT generates a feedback voltage proportional to the position change of the cylinder. The feedback voltage is used by the controller to determine the control variable of the system. Figure 4 shows a closed-loop diagram demonstrated this control mechanism (Liu & Tang, 2008).

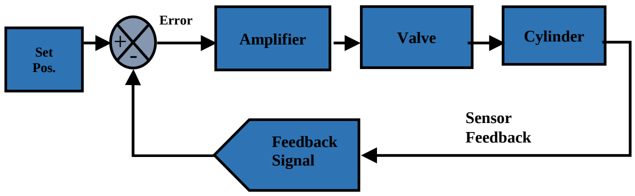
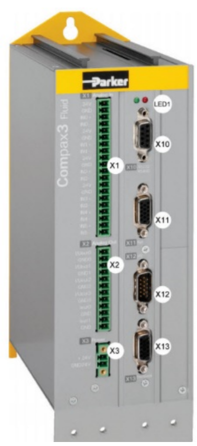


Figure 4. A closed-loop control system.

Compax3F Controller Configuration and Programming

Compax3F is a programmable hydraulics controller that interfaces with hardware components and implement control functions. The controller has modules to connect to six analog input devices, four analog output devices, and twelve digital input/output signals, as shown in Figure 5.



X1	Analog Inputs
X2	Analog Outputs
X3	24 VDC power supply
X10	RS232/RS485
X11	2. Feedback Type
X12	Inputs/Outputs
X13	1. Feedback Type

Figure 5. The Compax3F controller.

The controller is configured through Parker Servo Manager software. The software interface is shown below in Figure 6.

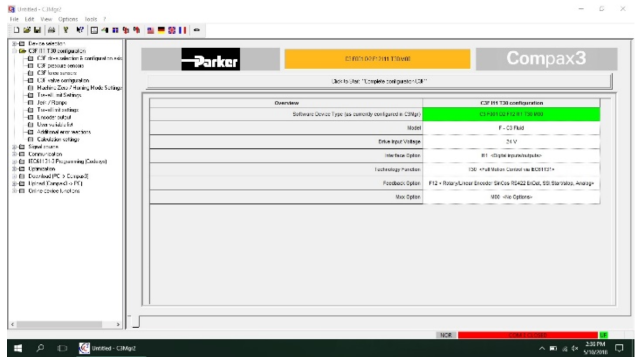


Figure 6. Parker Servo Manager.

The controller configuration includes the configuration of all the devices in the system and parameter setup of the control profile. The major configuration setups are

1. Axis selection and configuration
2. Sensor configuration
3. Valve configuration
4. Machine zero/homing mode setup
5. Travel limit setting
6. IEC61131-3 variable list for programming

The configuration is saved in a configuration file and downloaded to the controller for system function. Once the configuration file is completed and downloaded correctly, the controller establishes communication with all the input/output devices, and recognizes the type and parameter settings of these devices. In this system, the devices are the proportional direction control valve and the cylinder.

The controller can be programmed in CODESYS, a programming environment for control systems that can be used to develop IEC61131-3 programs. Control programs can be programmed in various formats including instruction list, structured text, sequential function chart, function block diagram, the continuous function chart, and ladder diagram. CODESYS has default functions including bit manipulation, numeric function, type conversion, selection function, trigger, numerator, timer, and PID control functions (Hanssen, 2017). It provides a convenient program-developing environment for controller programming. For this position control, a function block program has been created as shown in Figure 7. Major functions used in the program are jog function, power enable function, data conversion, motion reset function, absolute movement function, and set home function. The function block program illustrates the data flow and logic in executing the position control.

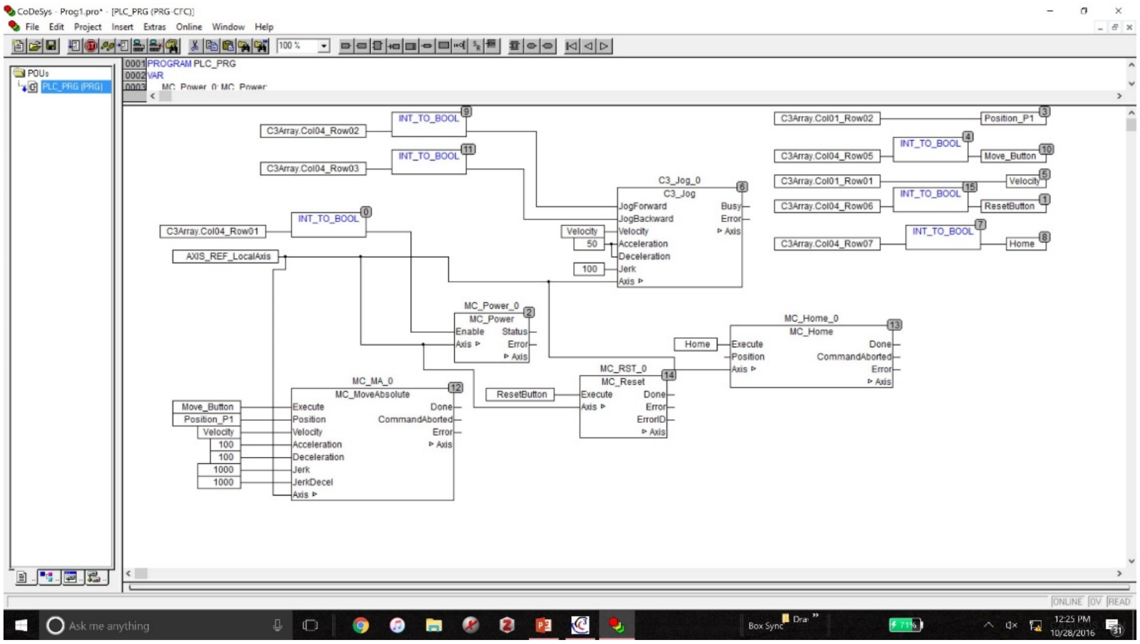


Figure 7. CODESYS programming.

The MC_Power function is designed to control the on/off status of the drive/cylinder. The major inputs of this function are the axis reference number of the cylinder and enable button from HMI interface, as shown in Figure 8.

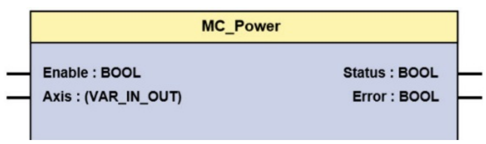


Figure 8. MC_Power function.

The MC_Home function is designed to execute a sequence for searching home position and cause the axis to move to home position. The major inputs of this function are axis reference number of the cylinder, Execute input to provide a valve starting the execution, and Position input to provide an absolute position, as shown in Figure 9.

Figure 9. MC_Home function.

The MC_Reset function is designed to reset all internal axis-related errors and will not affect the output of the functional block instances. The major inputs are the axis reference number and the Boolean signal to activate this function (Figure 10).

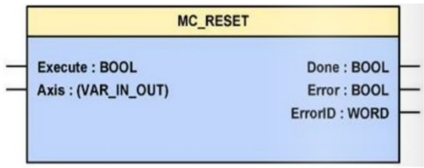


Figure 10. MC_Reset function.

The MC_MoveAbsolute function, Figure 11, is designed for the axis to move to an absolute position and uses the input valves. The inputs are the axis reference number, a Boolean signal to activate the function and values to set target position, velocity, acceleration, deceleration, and jerk.

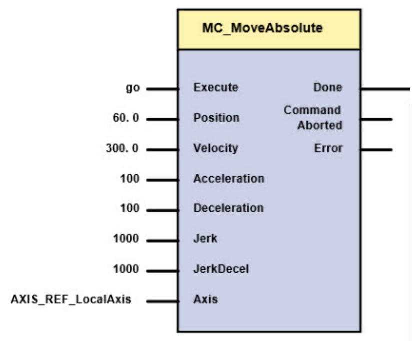


Figure 11. MC_MoveAbsolute function.

The completed CODESYS in CFC format is then linked to the Compax 3F configuration file in the Parker Servo Manager environment. This combined project configuration and programming file can be downloaded to the Compax 3F controller to implement control function.

System HMI Interface

An HMI interface is developed to provide a control panel to the position control system. The interface is programmed in Interact Xpress software, the layout of the control is designed as shown in Figure 12.

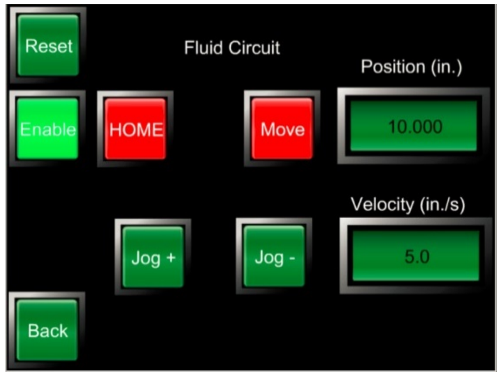


Figure 12. Position control panel.

The control panel contains seven buttons and two variable input boxes. Enable and Reset are Boolean buttons to enable the valve drive and reset the input variables for position and velocity control. The Home button will bring the cylinder piston to the pre-configured home position, and the Move button enables the motion control set by the input variables. Two Jog buttons (Jog+, Jog-) allow manual jogging of the cylinder piston on both directions. There are variable input boxes to set position and velocity values for the motion control. Also a Back button is included to navigate back to the previous window. For this position control system, a few more windows have been designed for instructions, as shown in Figures 13-15.

Figure 13. Starting window.

The starting window of the motion control application is as shown in Figure 13. Users can select one of the control applications to proceed from the fluid cylinder position control and a motor position control.

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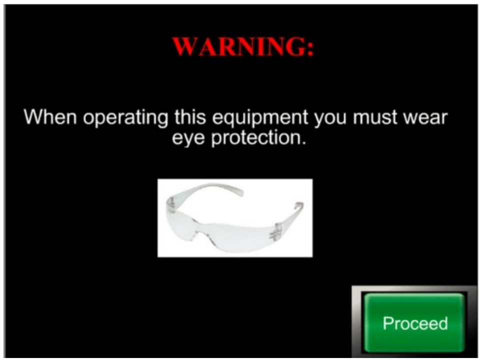

Figure 14. Instruction window (1).

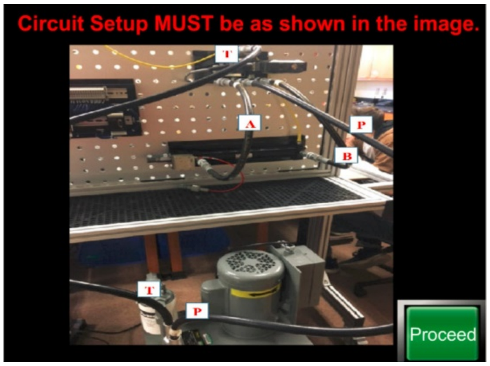

Figure 15. Instruction window (2).

The interfacing between this HMI interface and the application in Parker Servo Manager software is based on data tags created in Interact Xpress and the connection between the data tags and variables used in CODESYS program. Table 2 lists the data tags used and their connections with CODESYS variables.

Table 2. Data tag connections.

Function	Interact Express Tags	CODESYS Variables
Enable	C3.C.1904.1	C3Array.Col04_Row 01
Home Button	C3.C.1904.7	C3Array.Col04_Row 07
Jog Positive (+)	C3.C.1904.2	C3Array.Col04_Row 02
Jog Negative (-)	C3.C.1904.3	C3Array.Col04_Row 03
Velocity Input	C3.C.1901.1	C3Array.Col01_Row 01
Position Input	C3.C.1901.2	C3Array.Col01_Row 02
Move Button	C3.C.1904.5	C3Array.Col04_Row

		05
Reset Button	C3.C.1904.6	C3Array.Col04_Row 06

Performance Analysis

Due to some technical issues, the completion of the system setup and programming took extra time. Currently, the position control system is working properly. However, the data collection on system performance based on response times and accuracy responding to PID variables is currently conducted by an undergraduate student and a PhD student.

Conclusion

This automated electrohydraulic position control system is developed to introduce electrohydraulics and control theory to students in the Manufacturing Engineering and Technology program. This system provides students with experience of hardware configuration, programming, interfacing, and system integration. Due to the time limitation, the system performance analysis is not completed yet. The completed data collection and analysis results will be added to this paper soon.

References

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Biographies

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