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Design of 4-Bit Digital Valve Control System

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Abstract— **The digital valve hydraulic system is the best other option to the servo control systems in substantial scale applications like forging, rolling and some machining applications. As compared to proportional valve control systems it is more economical because of open loop control, Easy to operate because it is having on/off direction control valves. Where using the binary coded with program based control is used for precise control of the system. In this paper, we compare to traditional systems like proportional valve system and servo control system digital based 4-bit digital valve control system is better by comparing the parameters of both systems i.e Energy efficient, Control accuracy, Precision of control, Position tracking control and velocity control.**

Index Terms— **hydraulic valves, proportional valves, Accuracy control.**

I. INTRODUCTION

Digital hydraulics is probably the new technology in the fluid power area. It has been studied much during the last decade. It has the potential to replace traditional hydraulics in future. The concept of digital hydraulics has been around for a while, but only recently the concept of digital hydraulics in paper and pulp industry has been feasible. It replaces proportional valve applications with parallel groups of simple, quick acting, binary on/off valves. Accurate force, velocity, and position tracking control are the basic functions of modern hydraulic actuators. Digital hydraulics constitute several benefits such as energy reduction, repeatability, response, productivity, reliable, low cost of spares, fault tolerance, scalability [1,2].

PCM (Pulse Code Modulation) is one of the popular approaches of the digital valve based system. It is used to digitally represent sampled analog signals [1]. It is composed of series of control units in parallel. To obtain PCM from analog waveform at the source end of the communication circuit, the analog signal amplitude is sampled at regular intervals [3]. The on/off valves with low frequency can be used to achieve PCM control [3]. This paper presents a control strategy for a digital valve based position tracking system for a 4-bit digital valve control system. The idea is to use an open loop control strategy as a feedforward term to improve the accuracy, speed control, acceleration of a position tracking system [1].

II. CONSTRUCTION

The digital valves based control circuit shown Fig A.4-bit digital valve control circuit operated by solenoids. The digital valve circuit is contained in 16-spring retracted single acting Directional control valves, and one double-acting spring retracted Direction control valve used. For controlling 16-spring retracted DCV's are divided into 2-combinations and each combination has 8-DCV's and again these are split into Each combination into 2- sets of

DCV's and each set contains 4-DCV's are placed in series and connected in parallel. After connecting 8-DCV's (means 2-Sets of DCV's) are used to control the hydraulic cylinder Expansion, The remaining 8-DCV's (means 2-Sets of DCV's) are used to control the retraction. For measuring the flow at each DCV used the orifice flow meter with sharp-edged (K-factor is).All valves are operated by Solenoids, These solenoids are controlled with PLC ladder logic programming. Above mentioned cylinder is a normal hydraulic cylinder with prescribed dimensions. One hydraulic pump which gives the constant pressure and normal hydraulic reservoir to store the retracted fluid.

The assumption made in the circuit is

The pressure at any point is constant; Valves are ideal; No leakages entire the circuit; No Flow losses, Friction losses, pressure losses [1].

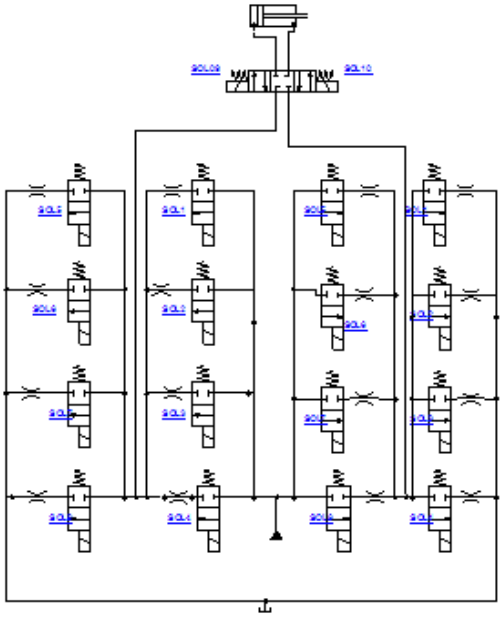

Fig.1.4-Bit digital valve control circuit operated by solenoids [1]

III. WORKING

The circuit executed in Automation Studio 6.1 simulation package. For actuation of solenoids according to our requirement made a PLC (Programmable Logic Controllers) Ladder logic program. For actuating the output coils in the program used the digital bit concept according to this concept we get 16 combinations of actuation of output coils like the below table.

TABLE I: DIGITAL BIT CONCEPT

4^{th} *Bit change*	3^{rd} *Bit change*	2^{nd} *Bit change*	1^{st} *Bit change*
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1

1	0	0	0
1	0	0	1
1	0	1	0
1	0	1	1
1	1	0	0
1	1	0	1
1	1	1	0
1	1	1	1

For constructing the ladder logic (PLC) program using components On-time delay timer, Counters and comparators, open and closed type switches.

A. TON (on delay timer)

- Count time base intervals when the instruction is true.
- The Timer on Delay instruction begins to count time base intervals when rung conditions become true. As long as rung conditions remain true, the timer adjusts its accumulated value (ACC) each evaluation until it reaches the pre-set value.
- The accumulated value is reset when rung conditions go false, regardless of whether the timer has timed out or not [4].

B. Counter

- Increments the accumulated value at each false to true transition and retains the accumulated value when the instruction goes false or when power cycle occurs.
- The CTU is an instruction that counts false to true transition. When this transition happens the accumulated value is incremented by one count.
- A CTU accumulation is reset by the RES instruction.
- If the accumulation value is over the maximum range then the overflow (OV) bit will be true [4].

C. Comparator

- This chapter gives the definition of comparison instructions and the way they are used. In general comparison, the instruction is used to test a pair of values to energize or de-energize a rung.

(i) Greater than comparator

- Greater than comparator is used to examine whether the sources inputs are greater than or not
- If the source input1 having address and source input 2 having another address the greater than comparator will compare the both, if negative integers are there it will be stored in 2's complement

(ii) Equal comparator:

- The equal comparator is used to examine whether the sources inputs are equal or not.
- If the source input1 having an address and source input 2 having another address the

comparator will compare the both if negative integers are there it will be stored in 2's complement.

D. Direction control valves (DCV)

Directional control valves are one of the most fundamental parts of hydraulic machinery as well as pneumatic machinery. They allow fluid flow into different paths from one or more sources. They usually consist of a spool inside a cylinder which is mechanically or electrically controlled. The movement of the spool restricts or permits the flow, thus it controls the fluid flow [9].

E. Solenoid operated DCV

These valves make use of electromechanical solenoids for sliding of the spool. Because the simple application of electrical power provides control, these valves are used extensively. However, electrical solenoids cannot generate large forces unless supplied with large amounts of electrical power. Heat generation poses a threat to extended use of these valves when energized over time. Many have a limited duty cycle. This makes their direct acting use commonly limited to low actuating forces [9].Often a low power solenoid valve is used to operate a small hydraulic valve (called the pilot) that starts a flow of fluid that drives a larger hydraulic valve that requires more force. A bi-stable pneumatic valve is typically a pilot valve that is a 3 ported 2 position detented valve. The valve retains its position in the loss of power, hence the bi-stable name [9].Bi-stability can be accomplished with a mechanical detent and 2 opposing solenoids or a "Magna-latch" magnetic latch with a polarity sensitive coil. Positive opens and negative closes or vice versa. The coil is held in position magnetically when actuated [6, 9].

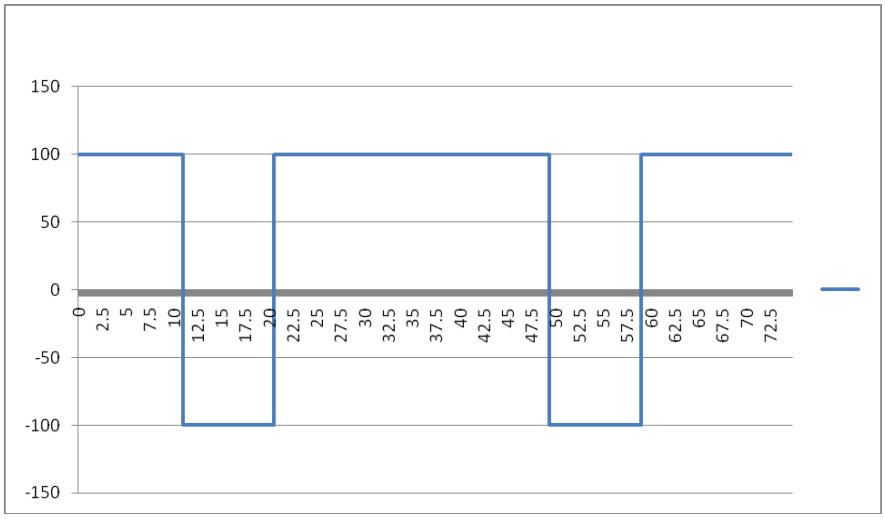

Fig.2.Graph of bi-directional(LVDT vs time)

F. Automation studio

- Automation Studio is a simulation package .it has many options like circuit design and simulation and plotting the graphs.

- Automation Studio Hydraulics functions are used for hydraulic system engineering purposes. Automation Studio Hydraulics includes a specific symbol library and uses modeling techniques such the Bernoulli's law and the gradient method.

- Automation Studio™ Hydraulics is the main aspect of Automation Studio: it is used to conceive and to test hydraulic systems while taking into account thermal parameters. It displays inside views of the elements in the schematics. The Automation Studio™ library includes additional elements such as commands and control devices (PID controller, CANbus, and servo-direction).

- Fluid power is one of the central elements in such simulation [7].

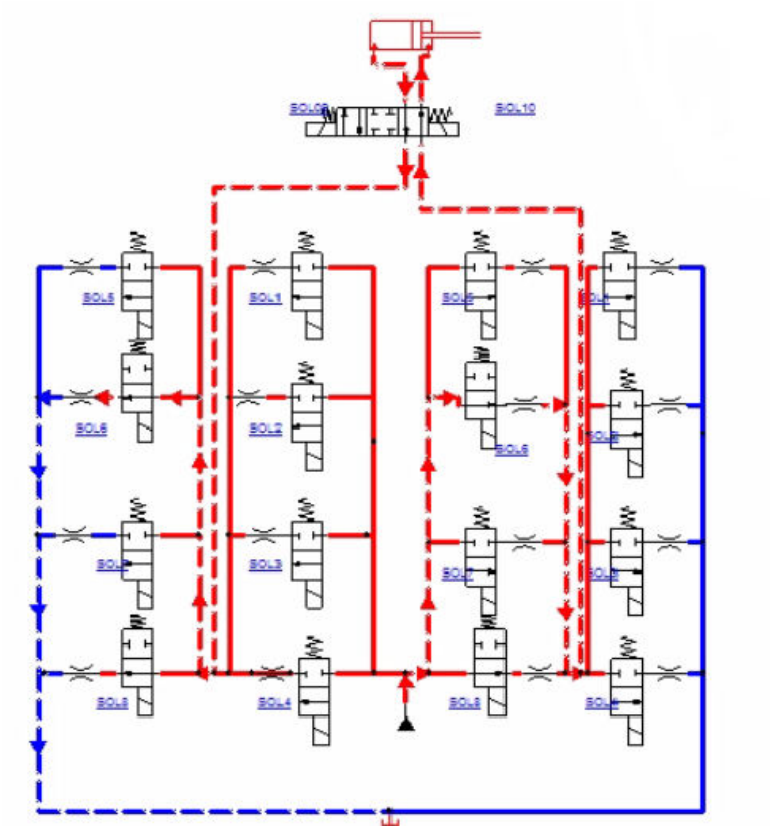

Fig.3.Simulation model of the circuit.

IV. DESIGN OF ORIFICE

Orifice meter is most generally used to quantify flow rates in channels, when the liquid is single-stage (instead of being a blend of gasses and fluids, or of fluids and solids) and all around blended, the flow is ceaseless as opposed to throbbing, the liquid possesses the whole pipe (blocking residue or caught gas), the flow profile is even and all around created and the liquid and flow rate meet certain different conditions. Under these conditions and when the orifice plate is developed and introduced by suitable models, the flow rate can without much of a stretch be resolved to utilize distributed formulae in light of significant research and distributed in industry, national and global principles [9].

Plates are normally made with sharp-edged circular holes and introduced concentrically with the pipe and with pressure recordings at one of three standard sets of separations upstream and downstream of the plate; these sorts are secured by ISO 5167 and other significant principles. There are numerous different potential outcomes. The edges might be circular or funnel-shaped, the plate may have an orifice an indistinguishable size from the pipe with the exception of a portion at crest or base which is impeded, the orifice might be introduced unpredictable to the pipe, and the pressure tapping's might be at different positions. A minor departure from these conceivable outcomes is canvassed in different measures and handbooks. Every blend offers to ascend to various coefficients of discharge which can be anticipated insofar as different conditions are met, conditions which vary starting with one write then onto the next [8].

Once the orifice plate is formed and presented, the stream rate can often be appeared with an acceptably low powerlessness basically by taking the square base of the differential pressure over the orifice's pressure tapping's and applying a proper steady. Indeed, even compressible streams of gasses that shift in pressure and temperature might be measured with satisfactory vulnerability by just taking the square roots of the absolute pressure and/or temperature, contingent upon the reason for the estimation and the expenses of auxiliary instrumentation [8].

Design of orifice diameter

$$Q=0.0851CA\sqrt{(\Delta p/Sp)} \quad [9]$$

Where

Q is discharged (m^3/sec)

C is Flow coefficient (0.64-0.76 for laminar flow)

C= (Actual discharge/Theoretical discharge)

A is Area of the Orifice (mm^2)

Δp is the pressure drop at orifice (Mpa)

Sp is specific gravity of the flowing fluid (constant) [9]

Where

Mpa-mega Pascal's (10^6)

We designed the Discharge of the flowing fluid in the order of 1:2:4:8 from the bottom of the circuit parallel sequence. Actually for achieving steady state condition in the binary coded digital valves us using the above series. By using the above series of discharge we design the 4-different diameters of orifice meter. By using the sharp-edged plate's orifice flow meter pressure drop will be more so it easy to design the diameter flow meter [1].

TABLE II: DESIGNED DIAMETER VALUES

Assumed values	*Ration*	*Discharge(m^3/s)*	*Diameter(mm)*
Q=0.4(m^3/s)	1	0.4	2.64
Δ_p=0.5 Mpa	2	0.8	3.74
S_p=1(Water)	3	1.2	4.60
	4	1.6	5.28

V. RESULTS AND PLOTS

Graphs plotted using the plotter in the automation studio simulation package. The below-shown graphs represent the speed and position tracking of the piston in the hydraulic cylinder when it is in the simulation.

- The limits of the plotter position Minimum value is 0 cm Maximum Value is +1000 cm.
- The limits for the plotter velocity Minimum value is -50 cm/s and Maximum value +50 cm/sec

From the below plots yellow color values represent linear speed, and the green color lines represent the linear position tracking values

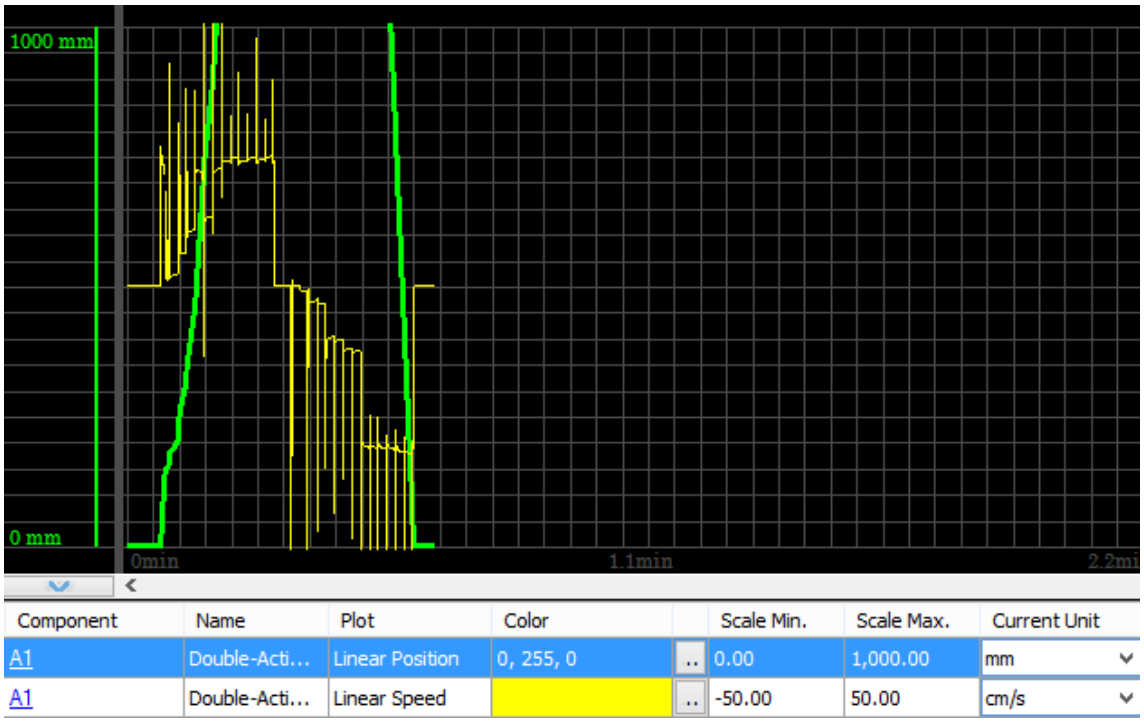

Fig.4.Position and velocity graphs through plotter tool

TABLE III: RESULTANT VALUES

S.No.	*Time(s)*	*Position(cm)*	*Velocity(cm/s^2)*
1	0	0	0
2	2	3.43	23.39
3	4	8.37	24.62
4	6	8.52	0
5	8	4.54	-30.05

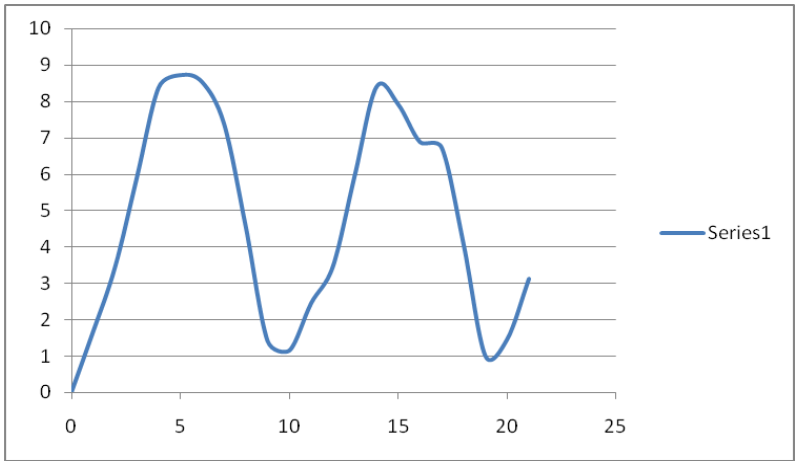

Fig.5.Position to time plot

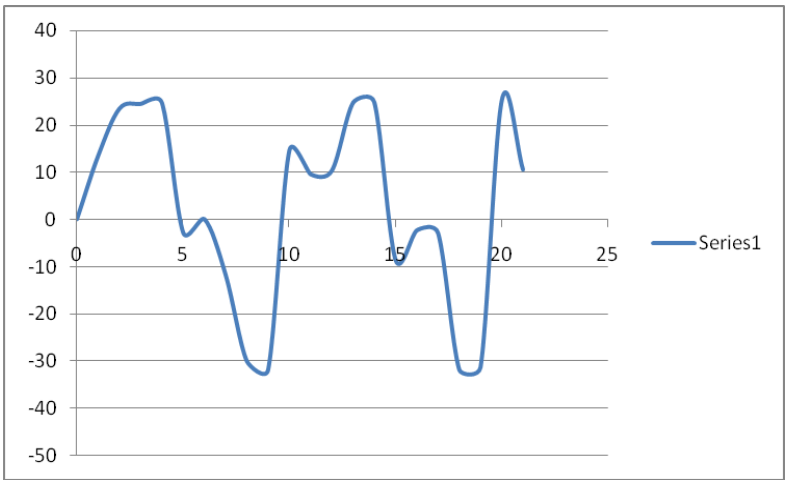

Fig.6.Velocity to time plot

VI. CONCLUSION

As compared to the all traditional control methods like servo control, proportional valve control methods, The 4-bit digital valve control has better accuracy and precession and easy to

control. From the graphs plotted in automation studio, we can say position tracking, velocity control is used for low frequency and low precision applications and error in the position tracking is within the tolerance limits.

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