Design of A Sequential Control Circuit for An Industrial Robot Using Cascading Method

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Abstract **A sequential control circuit for an industrial robot is to be designed to transfer hot billets leaving a furnace to the die of a forging machine. There is no universal circuit design method that suits all types of sequential circuits. A circuit designer should be aware that his method is economical for particular applications. There are four methods to design a sequential circuit. They are Karnaugh Veitch map, step counter, combinational logic circuit design and cascading method. This paper helps to know how to design a sequential circuit using cascading method. The circuit has been simulated by using Automation studio 5.3, software. A model of the industrial robot performing the above said operation is in a sequence C+A+B+C-B-A-. The pneumatic supply is used to control the sequence of operation. Also a model of robot has been made. The robot functions as the above said sequence. Using PLC program, the robot operation is controlled. The sequence of operation controlled by PLC program is also simulated using Automation studio 5.3 software.**

Keywords- **PLC Program, Cascading method, pneumatic control, Sieman Simatic Plc, Design, cylinders, DCV**

I INTRODUCTION

Automation is the use of control systems such as Pneumatics, hydraulics, electrical, electronics and computers to control industrial machinery and processes, reducing the need for human intervention. This is an era of automation where it is broadly defined as replacement of manual effort by mechanical effort, electrical effort, electronics effort and computer effort with all degrees of automation. In this paper degrees of automation are of two types. They are full automation with pneumatic power and full automation with PLC program. Material handling concept is an art and science of moving, packing and storing of productions. Automation plays a vital role in material handling by doing the sequence of operation automatically and helps in mass production. Two model of system has been designed and tested for its working with a help of a prototype model. The sequence of working of the automation model using pneumatic power has been designed by using cascading method. The working of the

Automation model using PLC program is also programmed and controlled by using Sieman simatic step win software. The Working of both automation with pneumatic power and full automation with PLC program were simulated with the help of automation studio software.

II EDIFICE OF OUR CIRCUIT

In our circuit, Cylinder C is used for the gripper opening. Cylinder B is used for the arm up and down movement. Cylinder A is used for the rotation of the body of the robot. The sequence of operation of the robot is C+A+B+C-B-A-. 'C+' is the extension of the cylinder C. When the cylinder C extends the gripper opens. 'A+' is the extension of the cylinder A. When the cylinder A extends the robot rotates to the predetermined angle. 'B+' is the extension of the cylinder B. When the cylinder B extends the robot bends to pick the object. These are the first three sequences, in which all the three cylinders are in extended positions. 'C-'is the retraction of the cylinder C. When the cylinder C retracts the gripper closes. 'B-'is the retraction of the cylinder B. When the cylinder B retracts the robot raises above. 'A- is the retraction of the cylinder A. When the cylinder A retracts the robot rotate back to its original position with the object. When the second three sequences are completed once again the first three sequences starts. That is, robot drops the object picked and then starts its cycle of working till the supply is stopped.
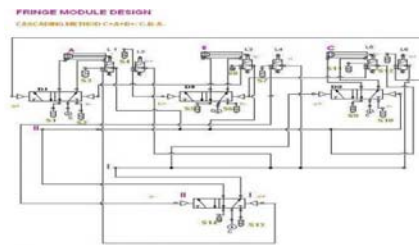

Fig.1 Cascade design

III STEPS FOLLOWED IN CASCADING
METHOD

A good number of pneumatic circuits are designed by intuitive method. Among the intuitive method, cascade method is found to be simplest and easiest where signal cut out is achieved by use of reversing valve.

1. On the basis of the cylinder motion sequence, the different positions of the cylinders are grouped and a code number or letter is assigned to each group for demarcation.
2. Each cylinder is awarded a code letter and their sequence is determined. The sequence is determined as C+A+B+C-B-A-.
3. The sequence is split in to groups with respect their sign convention. The positive sign indicates advance movement or extend movement and negative sign indicates retract movement.
4. The groups are split into groups as shown below
       C+A+B+/C-B-A-.
            I   II
5. This type circuit diagram helps to check the circuit diagram easily.
6. The circuit contains three numbers of 5/2-direction control valves for each cylinder.
7. One 5/2-direction control valve is used as cascading valve, which behaves as reversing valve. The number of cascading valve is determined according to the groups we had determined. Here it is two groups. So, one reversing valve is enough.
8. Each group has one cascading line with four pressure lines.
9. Two limit switches are required for each cylinder to check its extension and retraction. So, there should be 6 limit switches for our operation. In our operation we use 3/2 direction control valves as limit switches.

Table.1. Parts Description

S. No	Name of the part	Quantity	Details
1	Cylinder	3	Double acting
2	Direction control Valve	3	5/2 air operated Valve.
3	Cascading Valve	1	5/2 air operated Valve.
4	Cascading ports	8 for two lines	Three way port is used
5	Limit switches	6	3/2 air operated Valve.

With the above assumptions, we had designed the circuit as given below and the simulation has been seen.

IV WORKFLOW OF THE CIRCUIT DESIGNED-
SIMULATION

Step 1: C+

In fig 2, when the supply is on, cylinder C extends, that is the gripper is opened.

Step 2: A+

In fig 3, after the extension of the cylinder C, it hits the limit switch L6. The limit switch makes a change over in the pressure supply and activates the 5/2 DCV D1 and due to this action the supply enters cylinder A and the piston rod extends and the body of the robot rotates to the predetermined angle.

Step 3: B+

In fig 4, after the extension of cylinder A, the piston rod hits the limit switch L2. The limit switch makes a change over in the pressure supply and activates the 5/2 DCV D2 and due to this action the supply enters cylinder B and the piston rod extends. Due to this action, the arm of the robot bends down to pick the object.

After the first three sequences the three cylinders are in extended position that is, all are in positive sequence.

Step 4: C-

In fig 5, after the extension of cylinder B, the piston rod hits the limit switch L4. The limit switch makes a change over in the pressure supply and activates the 5/2 DCV, which acts as cascading valve. So, due to this action pressure transports from cascade line I to cascade line II.

Step 5: B-

In fig 6, after the transfer of pressure lines from I to II, 5/2 DCV D2 is activated on the right side. Due to this action supply makes the piston rod to retract. This action causes the arm of the robot to lift.

Step 6: A-

In fig 7, when the Cylinder B retracts, it activates the limit switch L3. Due to this action, 5/2 DCV D1 gets activated on the right side making the cylinder A to retract. This action makes the robot to return back to its original position. At this position the limit switch L1 activates. When limit switch L1 is activated, the gripper opens and releases the object. The cycle continues till the supply is stopped.
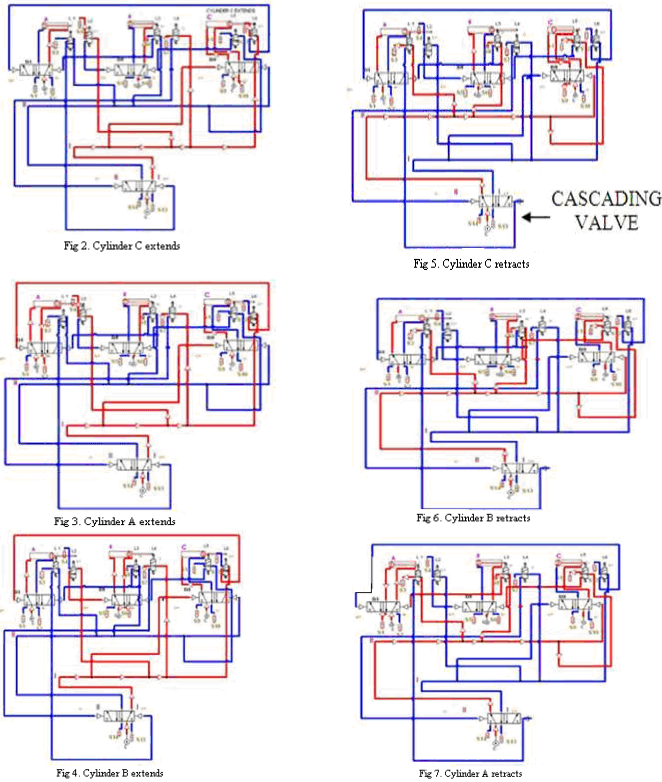
Fig 2. Cylinder C extends

Fig 5. Cylinder C retracts

CASCADING VALVE

Fig 3. Cylinder A extends

Fig 6. Cylinder B retracts

Fig 4. Cylinder B extends

Fig 7. Cylinder A retracts

Table 8: Components arrangements

| S.No	Name of the part	Description
1	Double acting cylinder C	Cylinder C is connected to a gripper
2	Double acting cylinder A	Cylinder A is connected to a rack and pinion arrangement for the rotation of the body of robot
3	Double acting cylinder B	It is used for the raising and lowering of the arm
4	Limit switches	Switches are placed in such a way that the movement of the piston rod in the cylinder is kept in check according to our requirement.
5	DCVs	Connection given according to the circuit shown above

Robot with Pneumatic power
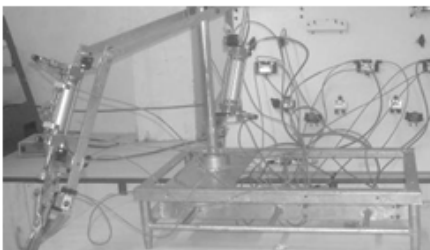
Fig. 8

V TECHNICAL INFORMATION OF THE COMPONENTS USED

CYLINDER

Barrel:

It is made of cold drawn aluminium honed to 25 mm.

Piston rod:

M.S. hard Chrome plated.

Seals:

Nitrile (Buha-N) Elastomer

End covers:

Cast iron graded fine grain from 25mm to 300mm

Piston:

Aluminium

Media:

Air

Temperature range:

0°c to 85°c

Cushions:

Adjustable standard on 400mm bore and above

RACK AND PINION ASSEMBLY

This rack and pinion attachment gives the rotary motion to the pneumatic robot. This block converts linear motion into rotary motion.

DIRECTION CONTROL VALVES

Direction control valve on the receipt of some external signal, which might be mechanical, electrical or a fluid pressure pilot signal, charges the direction or stops the flow of fluid in some part of the pneumatic/hydraulic circuit.

LIMIT SWITCHES

3/2 direction control is used as limit switches to control the motion of all the cylinders.

VI AUTOMATION USING PLC
PROGRAM

The PLC program has been written and its working has been checked by using automation studio software. The details are as follows

VII PARTS DESCRIPTION

The components used will be different from pneumatic power. The component description for the PLC program is given below

Table.3. Parts description

S. No	Name of the part	Quantity	Details
1	Cylinder with magnetic sensor	3	Double acting
2	Direction control Valve	3	5/2 air solenoid operated valve.
3	Magnetic sensor	6	Sensor is placed to have check for the movement of piston rod in the cylinder

VIII WORKFLOW OF THE CIRCUIT DESIGNED-
SIMULATION

Step 1: C+

In fig 10, when the trigger is given to the switch 'PA', solenoid m1 activates. This solenoid m1 in turn activates input switch m1. This input switch triggers solenoid q1.This solenoid q1 changes the pressure control of 5/2 DCV 1 and makes the piston of cylinder C to extend. The gripper gets open.

Step 2: A+

In fig 11, when the piston rod of cylinder C extends, it reaches the sensor C+. This gives pulse to the solenoid q3 of 5/2 DCV 2. This changes the pressure control of the DCV. This action makes the cylinder A to extend. The body of the robot rotates in the predetermined angle. The PLC circuit gets closed as per the sequence explained.

Step 3: B+

In fig 12, when the piston rod of cylinder A extends, it reaches the sensor a+. This gives pulse to the solenoid q5 of 5/2 DCV 3. This changes the pressure control of the DCV. To change the pressure control solenoid m3 in the circuit gets triggered. This gives input to the solenoid q5. This q5 solenoid changes the pressure control and the cylinder B extends. This action enables the arm of the robot to bend down.

Step 4: C-

In fig 13, when the piston rod of cylinder B extends, it reaches the sensor b+. This gives pulse to the solenoid q2 of 5/2 DCV 1. This changes the pressure control of the DCV. To change the pressure control, solenoid m4 in the circuit gets triggered. This gives input to the solenoid q2. This q2 solenoid changes the pressure control and the cylinder C retracts. This action enables the gripper of the robot to close. During this action the circuit gets closed for the solenoid q1.

Step 5: B-

In fig 14, when the piston rod of cylinder C retracts, it reaches the sensor C-. This gives pulse to the solenoid q6 of 5/2 DCV 3. This changes the pressure control of the DCV. To change the pressure control, solenoid m5 in the circuit gets triggered. This gives input to the solenoid q6. This q6 solenoid changes the pressure control and the cylinder B retracts. This action enables the arm of the robot to rise. During this action the circuit gets closed for the solenoid q5.

Step 6: A-

In fig 15, when the piston rod of cylinder B retracts, it reaches the sensor b-. This gives pulse to the solenoid q4 of 5/2 DCV 2. This changes the pressure control of the DCV. To change

the pressure control, solenoid m6 in the circuit gets triggered. This gives input to the solenoid q4. This q4 solenoid changes the pressure control and the cylinder A retracts. This action enables the robot to turn to its original position. During this action the circuit gets closed for the solenoid q3.

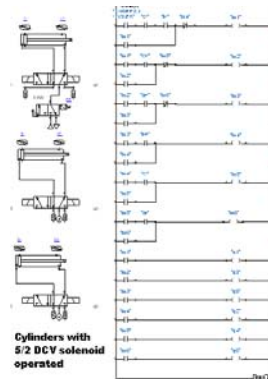PLC PROGRAM- LADDER DIAGRAM

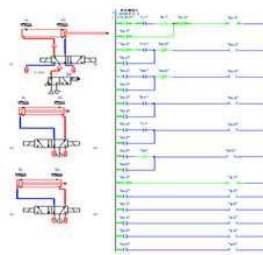Fig.9
WORK FLOW OF THE LADDER DIAGRAM
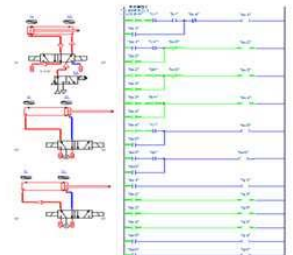
Fig.10. m1 activated, q1 activated

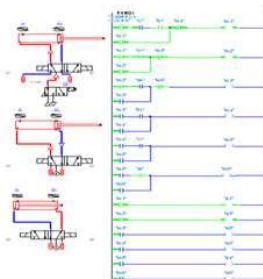Fig.13. m4 activated, q2 activated, q1 deactivated
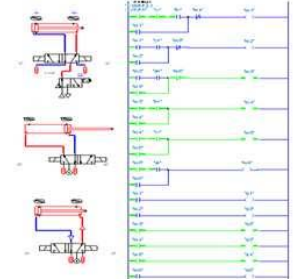
Fig.11. m2 activated, q3 activated

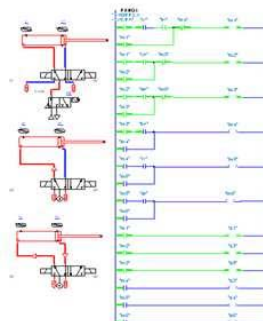Fig.14. m5 activated, q6 activated, q5 deactivated
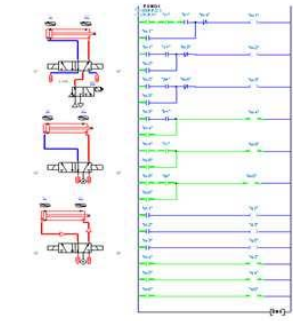
Fig.12. m3 activated, q5 activated

Fig.15. m6 activated, q2 activated, q1 deactivated

PLC works as per the instructions of the Siemanns Simatic Step7/ Microwin program. The ladder diagram which was designed and simulated by using automation studio software was booted to the siemanns simatic software of PLC and the robot is controlled as per the program fed.

IX   APPLICATION- Example

- To transfer hot billets leaving furnace to the die of a forging machine and then to transfer the forged work pieces from the forging machine on to a conveyor.
  - Can be used as a material handling system
- This unit can be used for clamping
- When the pneumatic arms are made smaller in size they can be used in automatic tool changes in CNC turning and drilling machines.

X ADVANTAGES OF CASCADE SYSTEM

- Circuit design, drawing and checking are very quickly accomplished
- Fault diagnosis and trouble shooting are very simple
- Required task by each cylinder and their signal elements is fully ensured.

XI   ADVANTAGES OF PLC

- PLC reduces the complexity of wiring required and changes can be more easily implemented

XII ADVANTAGES OF PNEUMATIC POWER

- Pneumatic power is more efficient in the technical field
- Quick response is achieved
- Simple in construction
- Easy to maintain and repair
- No fire hazard problem due to over loading
- Operation of arm is faster
- Continuous operation is possible with out stopping

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