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Automation of Bottle Manufacturing, Filling and Capping Process using Low Cost Industrial Automation

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Abstract: **The small scale industries go for manual operations to manufacture bottles, filling and capping them. These industries requires large amount of labour for operating the machines, and to increase the production rate. The designed low cost industrial automation process is best suitable for small scale industries to increase the production rate of manufacturing the bottles, filling the liquid and capping the bottles. The above process have been studied and designed a better low cost industrial automation process, which is performed by pneumatic actuators with electrical control and PLC's. The electric circuit have been designed such that, the sequence of operations are tested by using Fluidsim Pneumatic simulation software, and also the required ladder program is designed in the programmable logic controller. This leads precisely controlled actions of its operations, which permits the safe control of its operating process. The designed automation process is of programmable. The sequence of operations are such as automatic clamping, unclamping, injecting the molten material, filling and capping process of the bottles is determined. This is achieved through the use of simple devices like limit switches, relays, sensors, pneumatic actuators and electrical controls.**

Keywords— Fluidsim Pneumatic simulation software, PLC, Pneumatic actuators, relays

I. INTRODUCTION

The small scale industries use conventional methods for manufacturing the bottles, filling and capping the bottles. These bottles are filled manually and in unhygienic conditions which contaminates the products filled. Large amount of labour are required to perform these operations. The conventional process is converted into automaton process, by this method the production rate increases at a low investment. This is achieved through low cost industrial automation [10].

Automation is defined as a control system and technologies which reduces the human work in the production field [1]. Automation control system is that system which controls the process automatically and reduces the human mentor. Automation system has ability to initiate, adjust the process automatically and stop the process when desired output is obtained [5].

Low Cost Automation or Cost Effective Automation promotes cost oriented reference architectures and development approaches that properly integrate human skill. This can be achieved by introducing very simple devices such as limit switches, electrical relays, solenoid valves, pneumatic actuators [6, 7]. Use of simple devices utilizing relatively cheap and readily available components, to minimize or eliminate human effort in certain operations is called Low Cost Automation. The often-told reason not to go in for automation is the high costs involved compared to the investment in manpower. However this is only one of the aspects which most of the plant engineers look into while deciding their automation requirements. The main aim of Low Cost Industrial Automation is to increase Productivity and quality of products and reduce the cost of production.

II. FLUIDSIM PNEUMATIC SIMULATION SOFTWARE AND PLC PROGRAMMING

Fluidsim Pneumatics is a teaching tool for simulating pneumatics basics and runs using Microsoft Windows. It can be used in the combination with the Festo Didactic training hardware or independently. Fluidsim was developed as a joint venture between the University of Padeborn, Festo Didactic Company and Art Systems software in Padeborn.

A major feature of Fluidsim is its close connection with CAD functionality and simulation. Fluidsim allows DIN-compliant drawing of electro pneumatic circuit diagrams and can perform realistic simulations. Simply stated, this eliminates the gap between drawing of a circuit diagram and the simulation of the related pneumatic system. The CAD functionality of Fluidsim has been specially tailored for fluidics.

Fluidsim Pneumatic simulation software is used to design the pneumatic circuits and simulate the circuits. The electrical circuits for the automation process are designed and simulated.

PLC is a device which is designed to perform the logic functions. PLC stands for programmable logic controller. RICHARD E. MORLEY invented the first PLC in 1969. The PLC programming procedure replaced a wiring of the relays, timers etc. The PLC programming is written in high level language, which is easier for understandable of the more people [11]. Any machine can be controlled automatically by use of PLC. For automation of process write the program in the software then transfer the program to the PLC and after that connect the PLC to the machine [2]. A single PLC can run many machines at same time. The PLC has capability for handling several inputs and outputs signal. Allen Bradley PLC and Rslogix 500 plc programming software are used for automation of the process.

III. DESIGN SEQUENCE FOR AUTOMATION PROCESS OF BOTTLE MANUFACTURING, FILLING AND CAPPING THE BOTTLES

Initially when the power is on the system starts working the process. The cylinder A. activates and clamps the die block. Then piston of the cylinder B moves forward and injects the molten material in to die block and the piston goes back. Now the piston of cylinder A unclamps the die block and the bottle ejected on to the conveyor.

Now the bottles goes to the filling section and the sensor 1 detects the bottle and activates the cylinder C now the piston moves forward clamps the bottle and activates the cylinder D and the piston pushes the filler in to the bottle and then the cylinder v activates to open the nozzle and fills the required quantity. When the height of the liquid is sensed by the sensor 2 then cylinder v closes the nozzle, the piston of the cylinder D goes back and filler is moved up and the bottle gets unclamped and moves towards capping section.

Now the bottle goes to the capping section when the sensor 3 detects the bottle it activates the cylinder E and the piston moves forward and clamps the bottle. Now the cylinder F activated and the piston comes down and fixes the cap, the sensor 4 senses whether capping is done and then activates the piston of the cylinder F to retract, the cylinder E retracts and unclamps the bottle. The man at the last of the section collects the bottle from the conveyor belt.

The above sequence of operations with inputs and outputs of the PLC are shown in the below fig.1

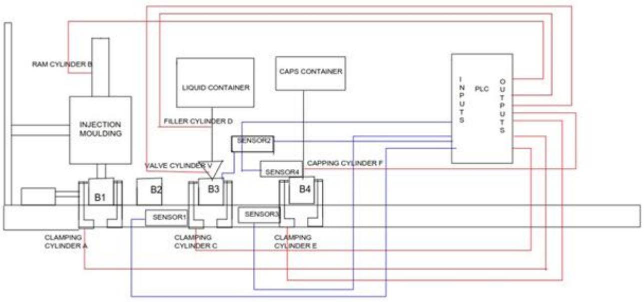

Fig 1: Inputs and Outputs connected to the PLC.

IV. SEQUENCE FOR AUTOMATION PROCESS OF MANUFACTURING, FILLING AND CAPPING OF BOTTLES

For automation of bottle manufacturing filling and capping process the sequence consists of Clamping the die block, moving the ram of injection moulding machine downwards, wait for a while and unclamp the die block, clamp the bottle, move the filler into the bottle, open the nozzle valve, after filling, close the nozzle, unclamp the bottle, clamp the bottle, move the capping motor downwards, after capping, move the capping motor upwards and unclamp the bottle. Thus consists of mainly three sections bottle manufacturing, filling and capping of the bottles.

That's the required sequence for overall process is A+B+B-A-C+D+V+V-D-C-E+F+F-E-. The interlocks occurs between B+ and B-, similarly in V+ and V-, F+ and F- to remove these interlocks relays are used. The total sequence is divided in to three operations. They are automation for manufacturing of the bottles by Injection moulding machine, automation of filling the bottle, automation of capping the bottles.

V. SEQUENCE FOR AUTOMATION OF BOTTLE MANUFACTURING PROCESS

For automation of the bottle manufacturing process the sequence consists clamping of the die block, move the ram downwards and inject the molten material in to die block, move the ram upwards, wait for a while and unclamp the die the bottle is ejected on to the conveyor.

For automation of this process the sequence is A+B+B-A-.

VI. DESIGN OF PNEUMATIC CIRCUIT FOR AUTOMATION OF BOTTLE MANUFACTURING PROCESS

a) Connect the working ports of one directional control valve to cylinder A and the working ports of other directional control valve to the cylinder B
b) The input port of each directional valve which is responsible for the motion of the piston is connected to the compressor.
c) The port of the directional valve which is responsible of moving out the pressure from the other side of the piston is connected to the exhaust.
d) The compressor is connected to the pressure source. The circuit is shown in below fig 2.

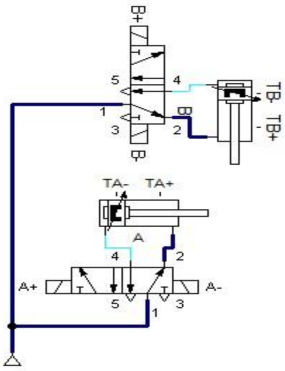

Fig 2: Design of Pneumatic circuit for automation of bottle manufacturing process

VII. DESIGN OF ELECTRIC CIRCUIT FOR AUTOMATION OF BOTTLE MANUFACTURING PROCESS

a) Connect the start button and solenoid valves A+, B+ to the NC (Normally Closed) of the relay K.
b) Connect the solenoid valves B-, to the NO (Normally Opened) of relay K.
c) Connect TB- NO with timer T as shown in circuit.
d) Connect the timer switch to the solenoid valve A-.
e) Connect the TB+ to relay K.
f) Hold the relay K with K and TA- NC.
g) The circuit is designed as per the circuit shown in fig 3 below.

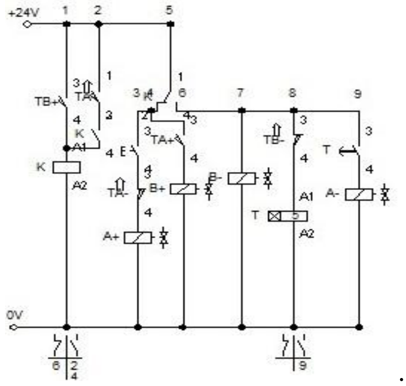

Fig 3: Design of Electric circuit for automation of Bottle manufacturing process.

VIII. SEQUENCE FOR AUTOMATION OF FILLING THE BOTTLES

For automation of the filling process the sequence consists of clamp the bottle, inject the filler in to the bottle, open the valve, fill the bottle up to required quantity, close the nozzle valve, eject the filler from the bottle, and unclamp the bottle. The sequence for this process is C+D+V+V-D-C-

Cylinders C, D, V are used for clamping of the bottle, movement of the filler, and nozzle valve open or close respectively.

IX. DESIGN OF PNEUMATIC CIRCUIT FOR AUTOMATION PROCESS OF FILLING THE BOTTLES

a) Working ports of each cylinder C, D, V are connected to working ports of each directional control valve.
b) The input port of each directional valve which is responsible for the motion of the piston is connected to the compressor.
c) The port of the directional valve which is responsible of moving out the pressure from the other side of the piston is connected to the exhaust.
d) The compressor is connected to the pressure source, as shown in fig 4.

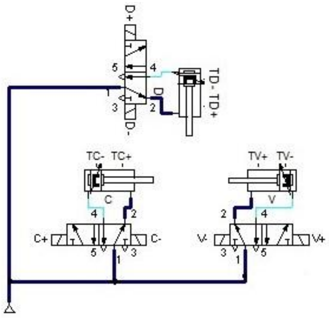

Fig 4: Pneumatic circuit design for automation process of filling the Bottles.

X. Design of Electric Circuit for Automation Process of Filling the Bottles

a) The sensors have three terminals one is connected to +ve, -ve and the other is output.
b) The output of sensor 1 is connected to the relay K2 and the output of the sensor s2 is connected to relay K3.
c) The relay K2 is hold with K2 NO and TV+ NC.
d) The relay K3 is hold with K3 NO and TC- NC
e) The solenoid C+ is connected to K2
f) TC+ NO and the solenoid D+ are connected to K2
g) TD+ NO and solenoid V+ are connected to K2.
h) The solenoid V- is connected to K3.
i) TV- NO and the solenoid D- are connected to K3.
j) TD- and the solenoid C- are connected to K3, as shown in below fig 5.

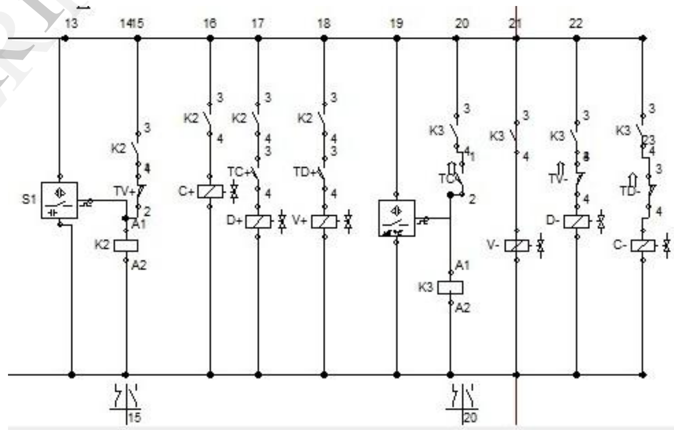

Fig 5: Design of Electric circuit for automation process of filling the bottles.

XI. SEQUENCE FOR AUTOMATION OF CAPPING THE BOTTLES

For automation of capping process the designed sequence is clamp the bottle, movement of the capping motor, unclamp the bottle. For automation of this process the designed sequence is E+F+F-E-

Two double acting pneumatic cylinders E and F are used for clamp the bottle and to the capping motor respectively.

XII. DESIGN OF PNEUMATIC CIRCUIT FOR AUTOMATION PROCESS OF CAPPING THE BOTTLES.

a) Each double acting pneumatic cylinder's working ports are connected to working ports of each double solenoid directional control valves.
b) The input port of each directional valve which is responsible for the motion of the piston is connected to the compressor.
c) The port of the directional valve which is responsible of moving out the pressure from the other side of the piston is connected to the exhaust.
d) The compressor is connected to the pressure source, as shown in fig 6.

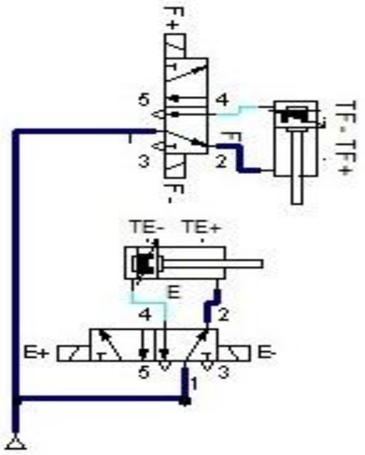

Fig 6: Pneumatic circuit Design for automation process of capping the bottles.

XIII. DESIGN OF ELECTRIC CIRCUIT FOR AUTOMATION PROCESS OF CAPPING THE BOTTLES

a) The +ve and –ve terminals of the sensor 3 and sensor 4 are connected to power supply and ground as shown in below fig 7.
b) The output terminals of the sensor 3 is connected to relay K4 and the output of the sensor 4 is connected to relay k5.
c) The relay K4 is hold with k4 and TF+ NC.
d) The relay K5 is hold with K5snd TE- NC.
e) The solenoid E+ is connected to K4.
f) TE+ and solenoid F+ is connected to K4
g) The solenoid F- is connected to F
h) The solenoid E- and TF- are connected to K5.

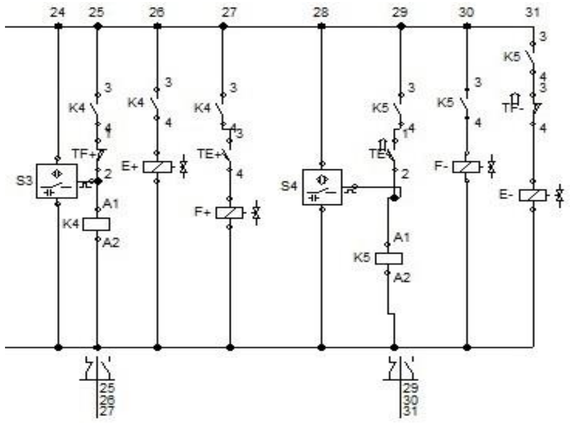

Fig 7: Design of electric circuit for automation process of capping the bottles.

XIV. SIMULATION FOR AUTOMATION PROCESS OF MANUFACTURING, FILLING AND CAPPING OF THE BOTTLES

The electric circuit that designed is drawn in the Fluidsim Pneumatic simulation software by choosing the required components from the components library and the drawn circuit is shown in below fig 8.

After drawing the circuit press the simulation button and circuit is ready for simulation then press the start button the injection moulding process starts, when the sensors are activated assigned operation is done.

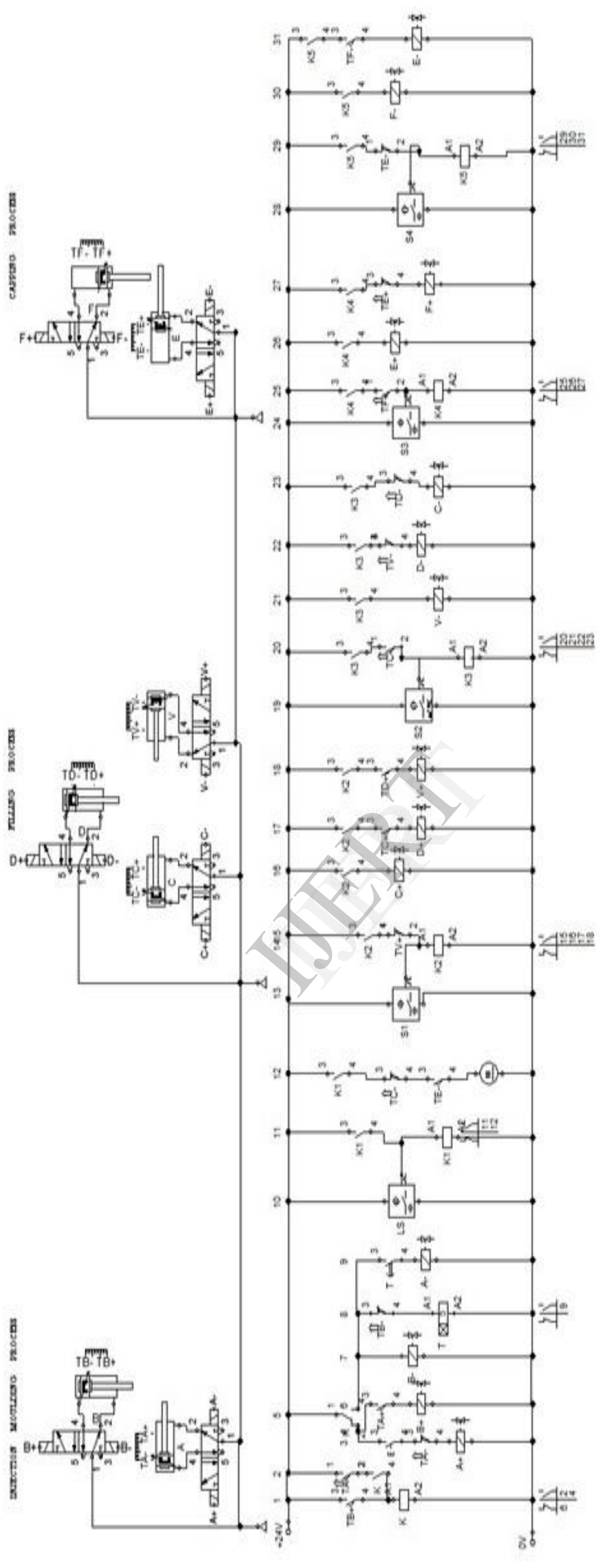

Fig 8: Design of Electric circuit for entire automation process in Fluidsim pneumatic simulation software

XV. LADDER PROGRAMMING IN RSLOGIX 500 SOFTWARE

The ladder program for the automation of bottle manufacturing, filling and capping process is shown below and the following tables show inputs and outputs that are assigned to the Allen Bradley PLC.

Table 1: Inputs assigned in Allen Bradley PLC.

START BUTTON	I:0/0
Forward position sensor of cylinder A is TA+	1:0/1
Retract position sensor of cylinder A is TA-	I:0/2
Forward position sensor of cylinder B is TB+	I:0/3
Retract position sensor of cylinder B is TB-	I:0/4
Retract position sensor of cylinder C is TC-	I:0/5
Motor start Sensor	I:O/6
Forward position sensor of cylinder C is TC+	I:0/7
Sensor 1	I:0/9
Forward position sensor of cylinder D is TD+	I:0/10
Forward position sensor of cylinder V is TV+	I:0/11
Sensor 2	I:0/12
Retract position sensor of cylinder D is TD-	I:0/13
Retract position sensor of cylinder E is TE-	I:0/14
Sensor 3	I:0/15
Forward position sensor of cylinder E is TE+	I:0/16
Retract position sensor of cylinder F is TF-	I:0/17
Forward position sensor of cylinder F is TF+	I:0/18
Sensor 4	I:0/19
Retract position sensor of cylinder V is TV-	I:0/20

Table 2: Outputs assigned in Allen Bradley PLC

Solenoid valve of clamping cylinder A to move forward is A+	O:0/0
Solenoid valve of ram cylinder B to move forward is B+	O:0/1
Solenoid valve of ram cylinder B to move Reverse is B-	O:0/2
Solenoid valve of clamping cylinder A to move reverse is A-	O:0/3
DC motor on	O:0/4
Solenoid valve of clamping cylinder C to move forwards is C+	O:0/5
Solenoid valve of filler cylinder D to move forwards is D+	O:0/6
Solenoid valve of cylinder V for valve opening is V+	O:0/7
Solenoid valve of cylinder V for valve closing is V-	O:0/8
Solenoid valve of filler cylinder D to move reverse is D-	O:0/9
Solenoid valve of clamping cylinder C to move reverse is C-	O:0/10
Solenoid valve of clamping cylinder E to move forwards is E+	O:0/11
Solenoid valve of capping cylinder F to move forwards is F+	O:0/12
Solenoid valve of capping cylinder F to move reverse is F-	O:0/13
Solenoid valve of clamping cylinder E to move reverse is E-	O:0/14

The connections of inputs and outputs of PLC are shown in below

Fig 9: Inputs and Outputs of PLC for automation of Injection Moulding process

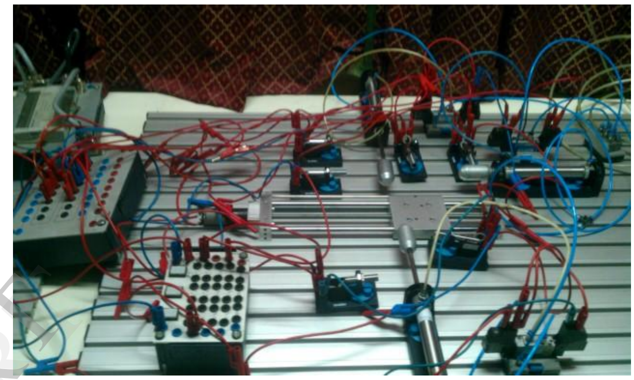

Fig 10: Inputs and Outputs of PLC for automation of filling the bottles

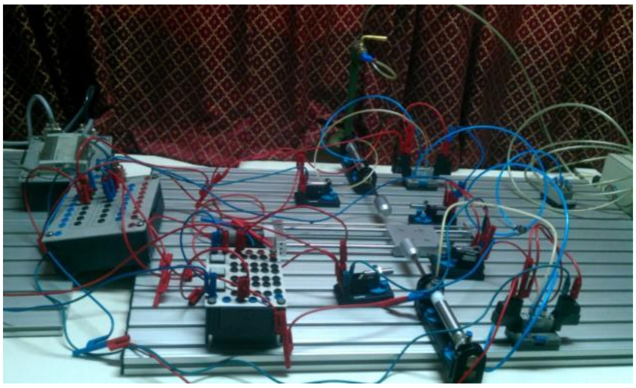

Fig 11: Inputs and Outputs of PLC for automation of capping the bottles

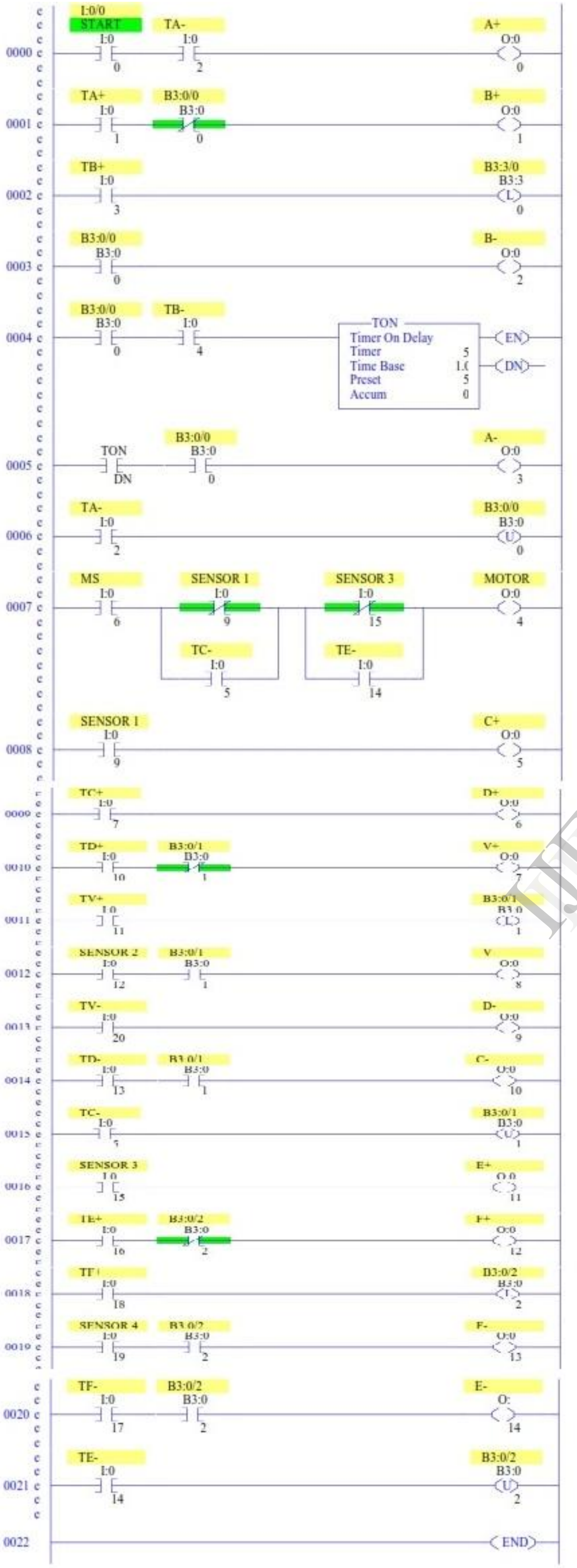

Fig 12: Ladder Program for Automation Process

XVI. CONCLUSION

The designed low cost industrial automation process is of programmable. The automation process has preciseness and accuracy in their operations, which is controlled through its controllers. The sequence of operations are such as automatic clamping, de-clamping, injecting the molten material, filling and capping process of the bottles are essential in industries to increase its production rate. Therefore, the required ladder program is designed in the programmable logic controller to its operating process. This is achieved through the use of simple devices like limit switches, relays, sensors, pneumatic actuators and electrical controls. The electric circuits are designed and the sequence of operations are tested by using Fluidsim Pneumatic simulation software.

The Automation process helps in reducing the time taken for the process to be completed. The Implementation of Low Cost Industrial Automation , particularly in small scale industries with simple usage of devices like pneumatic, actuators with electrical control to the existing conventional methods will make the automation at low cost to yield higher productivity.

XVII. FUTURE SCOPE

A scope for automation process to reduce the time required for testing the quality of Bottles. There is also a scope for automation process to measure the quality of the liquid filled in the bottles. The production rate is to be stored in the PLC. A record of the data like material availability, machines availability should be integrated with PLC for optimum utilization of machines to increase the production rate.

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