International Journal on Emerging Technologies (Special Issue on ICRIET-2016) **7**(2): 158-163(2016)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

PLC based Automated Flow Control in Cold Drinks Manufacturing Industry

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(Received 16 September, 2016 Accepted 19 October, 2016)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Automation is the use of different control systems for operating equipments such as processes in factories, aircraft and other applications with reduced human power. PLC's are very flexible, space efficient, cost effective and reduced complexity and by programming the PLC we control the entire system. Our paper, "PLC based automated flow controlled mixing, bottle filling and capping in cold drinks manufacture industry", mainly deals with mixing of various liquids and simultaneous filling and capping of bottles. Here mixing of various liquids takes place in flow controlled manner in containers and bottle filling and capping is done in a synchronized manner, where desired volume is filled in the bottles. The entire system is time saving and flexible. The bottle filling and capping operations are controlled using a PLC's. Some parameters such as sensors, motor, flow control valve and agitator are used to control operation of proposed work. Programmable logic controller Bosch Rexroth IndraLogic_L10 was used to control and automate the system by ladder logic diagram software.

Keywords: PLC, Automation, Sensors, Agitator, Cold drink Industry.

I. INTRODUCTION

In today's super fast moving and highly competitive world of industrial sector, a company must be cost effective, flexible and also efficient to survive. Nowadays we are shifting towards a world of automation and intelligent systems. The electronics applications are not only limited to the field of computers and communications but, they are also approaching every field. In these age of computers, automation in process of sensing, monitoring of changes and storing the changes per millisecond which is involved in experiment with high accuracy. Moreover, the tasks which are to be repeated many times with same sensitivity and accuracy can be successfully completed using automated instruments. Industrial automation helps to meet the demands such as more productivity, better accuracy, better quality and optimum utilization of available resources and manpower. Automation converts manual operations into semi- automatic or automatic operations by means of mechanical, computer and electronic systems, which is used for increasing efficiency of machine. PLC (Programmable Logic Controller) works as industrial computer, which reduces man power and increases productivity with less time and cost. The purpose of this project is to increase productivity, in preparation of cold drinks, with less time and to reduce the efforts of the workers in material handling. Some of the related works are as follows: In [1] author explains working of batch/process control system using Allen-Bradley batch/process control system. This system involves mixing of different kinds of liquid into mixer with control over the flow rate of liquid. In paper [2] author mainly concentrate on process of automatic bottle filling using PLC. Method involved in bottle filling is placing bottle on conveyor belt and filling a bottle at a time, which consumes more time. This paper explains simultaneous filling of bottles based on user defined volume. It overcome drawback of time consumption. The work given in [3] explains automatic filling and capping process controlled using PLC. Filling is done based on desired volume and actuators are used for capping process. The entire system is flexible and time saving, as it makes use of PLC.

In [4] author presents an overview of Mixing & Blending Templates applied to batch control system. This helps in time saving while complying with S88 standard. In S88 Batch concept, devices are configured as control modules, and grouped as equipment modules based on function groups. In [5] demonstrate different possible process steps involved in mixing and blending process. It mainly deals with properties of materials such as viscosity and air incorporation, etc. required in preparation of beverages. In paper [6] mainly deals with industry automation using Siemens Technology. It mainly focuses on increased production capacity at Coca-Cola industry. Paper [7] explains about automation in manufacturing. It mainly describes the components and working of those components required for the automation of manufacturing such as, sensors, robots, etc. The rest of the paper described as follows: Section II explains the proposed work, section III describes block diagram, components required are listed in section IV, section V gives the flow chart, simulation and results are explained in section VI and section VII concludes the work.

II. PROPOSED WORK

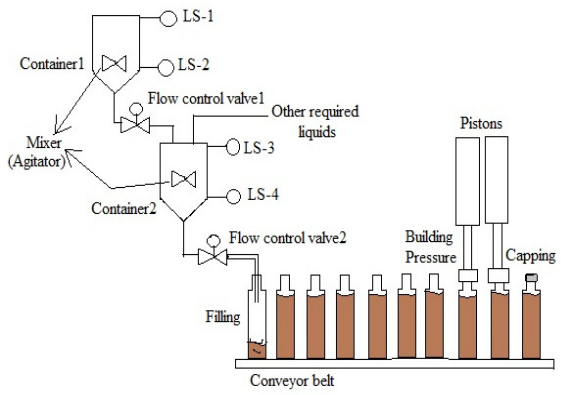


Fig. a: Proposed Model.

The proposed model for cold drink manufacture is as shown in figure a. The main aim of this paper is to design and build the system, which can be able to prepare, fill defined volume of cold drink in bottle followed by capping. PLC is used as a control system for controlling all the activities in this process. Push buttons and sensors are used as inputs, which send signals to the PLC and PLC respond to the given input. This response normally contains activation or deactivation of output devices. Depending on input signal of level sensor of container, liquid starts to flow into the container.

The flow of different liquid is controlled by setting knob of flow control valve. At set time, mixing of liquid in container1 and container2 starts. Container1 contains flavoring liquid and container2 contains other liquid along with flavoring liquid. Once mixing process is completed, filling of liquid in the bottle is done which is kept on the conveyor belt sensed by IR sensor. In this paper, we make use of three IR sensors, they are as follows: One to detect bottle at the filling process, other at building pressure and lastly at capping stage of bottle. Once filling process get over, pressure is build in the bottle where piston is used to create pressure in the bottle and then finally capping of bottle is performed with the help of another piston. The process of filling the bottle, building pressure in the bottle and capping of the bottle take specified amount of time to perform the required tasks.

III. BLOCK DIAGRAM

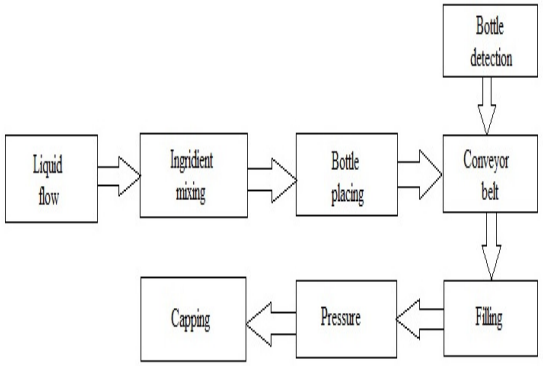


Fig. b: Block diagram.

The block diagram of basic components used in mixing and bottles filling for the preparation of cold drink is as shown in figure b. The components used are two Push button switches, four Level sensors, three IR sensor, Flow control valve, Agitator, Conveyor belt and Pistons.

The description of the Components used

a. Liquid flow

Here two containers are used to collect the liquid. Each container contains two level sensors i.e., ON sensor and OFF sensor. When OFF sensor goes high, liquid starts to flow into the container until ON sensor becomes high i.e., liquid stops flowing into the container. Here container1 is used to store flavoring liquid and container2 is used to store both flavoring liquid and other required liquids.

b. Flow control valve

Depending on output of the ON and OFF level sensor, liquid starts flowing through flow control valve where its flow/speed of liquid is controlled. The formula to calculate flow control is given in equation1,

$$\mathbf{Q = C_v\sqrt{\Delta P/G}} \qquad \mathbf{(1)}$$

Where, Q is flow rate, C_V is valve size coefficient, ΔP is pressure difference between ends of flow control valve, G is specific gravity of fluid.

c. **Mixing**

Thirteen different liquids present in the container is now mixed uniformly, such that all different liquid mix up precisely. To mix these liquids uniformly, agitator is used. These liquids are mixed continuously until there is liquid flow into container, for specified amount of time. Hence, cold drink is now ready.

d. **Timers**

Timer is one of the function in PLC which performs activation or deactivation, of the task to be performed, for or after specified amount of time.

(i) ON delay timer

When timer input goes high, after preset time is elapsed, the ON delay timer gets activated and it gets deactivated when its input goes low.

(ii) OFF delay timer

When timer input goes high, OFF delay timer gets activated. When timer input goes low, after preset time is elapsed, OFF delay timer goes low.

(iii) Pulse delay timer

When timer input goes high, timer gets activated for specified preset time and then resets even it has high input.

e. **Bottle placing**

Here bottle is placed onto the conveyor belt. And condition for placing bottle is that diameter of the bottle should be less than the width of the conveyor belt.

f. **Conveyor belt**

Conveyor belt is motor controlled. It must be strong enough to bear weight of the bottle. Motor is used to rotate the conveyor belt where, motor is operated on PLC logic.

g. **Bottle detection**

Bottle detection process will be carried out using sensors. Here we make use of three IR sensors which detects only non-metal items. Among three sensors, first sensor is used to detect bottle at filling process, second sensor is used at stage of building pressure inside the bottle and final third sensor is used at the capping process.

h. **Filling**

Once the preparation of cold drink is completed, filling process begins. When first IR sensor gives high input, filling process of the bottle starts for predefined time. During this time, conveyor belt stops moving and it get restart after specified time is elapsed.

i. **Pressure**

In this process, pressure is in need to be build inside the bottle. This is done, when second IR sensor gives high input, for predefined time. To build high pressure in the bottle, piston is used to blow.

j. **Capping**

Finally, capping of the bottle has to be done, followed by filling and pressure process. When third IR sensor gives high input, conveyor belt is stopped and another piston is actuated to complete the capping process of the filled bottle.

IV. COMPONENTS REQUIRED

a. Hardware Requirements

Sensors. A sensor is a device that measures a particular characteristic of an object or system. Some sensors are purely mechanical, but most sensors are electronic, returning a voltage signal that can be converted into a useful engineering unit. Sensors take advantage of the mechanical or electrical response of its components to relate the response to a relevant quantity. In the field of engineering, sensors are used in test and monitoring applications. Sensors are used in everyday objects such as touch-sensitive elevator buttons (tactile sensor) and lamps which dim or brighten by touching the base. There are also innumerable applications for sensors which include cars, machines, aerospace, medicine, manufacturing and robotics.

Conveyor Belt. A conveyor belt is one of many types of conveyor systems. The belt is a loop of flexible material used to mechanically link two or more rotating shafts, most often parallel. A belt conveyor system consists of two or more pulleys (sometimes referred to as drums), with an endless loop of carrying medium that rotates about them. One or both of the pulleys are powered, moving the belt and the material on the belt forward. The powered pulley is called the drive pulley while the unpowered pulley is called the idler pulley.

DC Motor. DC motors have been used in industrial applications for years. Coupled with a DC drive, DC motors provide very precise control. DC motors can be used with conveyors, elevators, extruders, marine applications, material handling, paper, plastics, rubber, steel, and textile applications.

Software Requirements

IndraControl L10. The control Indra Control L10 is a modular and scalable control. It combines the benefits of a compact small control with a standardized I/O system on the basis of terminal technology.

It is a hardware platform that can be used for PLC applications.

IndraWorks Engineering software. This is the universal tool of Bosch Rexroth for efficient software engineering. This also use to program and interface with Hardware.
(i) PLC and motion logic programming based on CoDeSys V3 with object-oriented language extensions.
(ii) Intelligent, wizard-supported operation.
(iii) Comprehensive software libraries compliant with IEC 61131-3 and PLC open.
(iv) Standardized interfaces such as FDT/DTM, connection of version control systems and automation interface.
(v) Detailed diagnoses.

V. FLOW CHART

Flavoring liquid

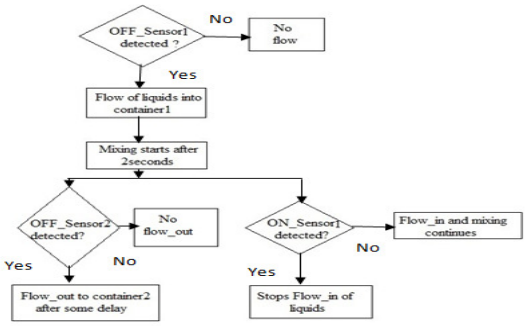


Fig. c: Flow chart for the preparation of flavoring liquid.

The flow chart for the preparation of Flavoring liquid is as shown in figure c. When OFF_Sensor1 of the container1 become low, no liquid flows and when it goes high various liquids starts flowing into the container1. After specified time, mixing of these liquids takes place using agitator until ON_Sensor1 of the container1 goes high. When ON_Sensor1 goes high, liquid flow into the container1 stops. When OFF_Sensor2 of the container2 goes high, liquid present in the container1, i.e., flavoring liquid, flows into the container2 along with other liquids.

Preparation of cold drink:

Figure d, gives flow chart for the preparation of cold drink. When OFF_Sensor2 of the container2 is low, no liquid flow into the container2 and when it goes high flavoring liquid and other required liquids flows into the container2.

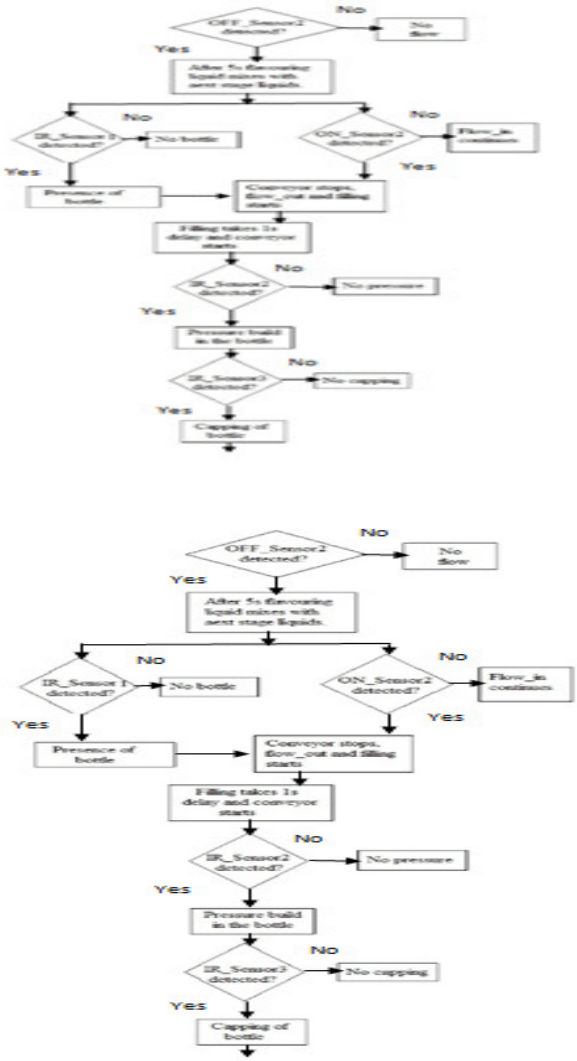


Fig. d: Flow chart for the preparation of cold drinks.

After preset time, these liquid starts mixing. When ON_Sensor2 of the container2 is low, flow in continues. Filling process starts when ON_Sensor2 goes high and IR_Sensor1 is detected, at which conveyor belt get stopped. When IR_Sensor2 is detected, pressure is built inside the bottle where piston is actuated for this. Finally, when IR_Sensor3 is detected, capping process takes place.

VI. SIMULATION RESULTS

a. Ingredient Required

i. Flavoring liquid

Table a: Ingredients needed to prepare flavoring liquid.

Ingredients	Volume of the ingredients
Food grade gum Arabic	10mL
Orange oil	3.5mL
Water	3mL
Lime oil	2.75mL
Cassia oil	1.25mL
Lemon oil	1.0mL
Nutmeg oil	1.0mL
Coriander oil	0.25mL
Neroli oil	0.25mL
Lavender oil	0.25mL

ii. Preparation of Cold drinks

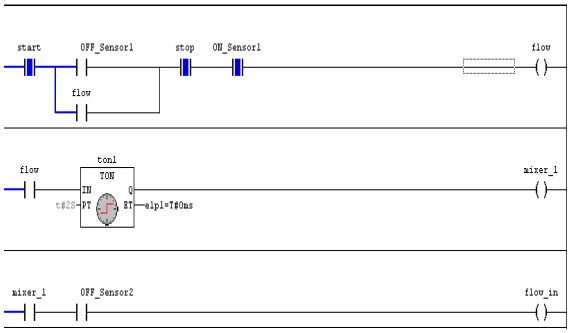
Table b: Ingredients needed to prepare Cold drink.

Ingredients	Volume of the ingredients
Sugar syrup	3000mL
Caramel color	30mL
Citric acid	17.5mL
Flavoring	10mL
Caffeine (optional)	2.5mL

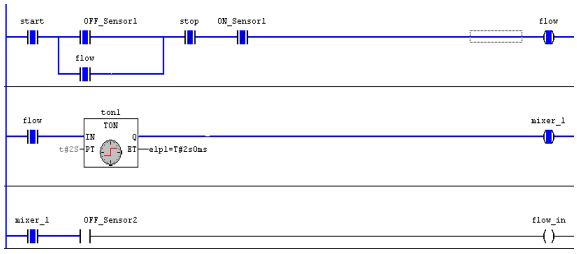
b. Ladder Diagram

Using Indralogic engineering works, ladder diagram is simulated. The simulation results of the ladder diagram are shown in figure f. Ladder diagram was developed for relay and switching control circuits. It is the graphical representation of relay logic hardware circuits PLC program. The ladder diagram has two power rails, which are placed vertically on each side of the diagram, and rungs, which are placed horizontally between the power rails. The power rails are the source of power in the circuit, where the left rail is the voltage and the right rail is neutral (AC) or ground (DC). The ladder diagram for the liquid mixing, filling and capping is as given below.

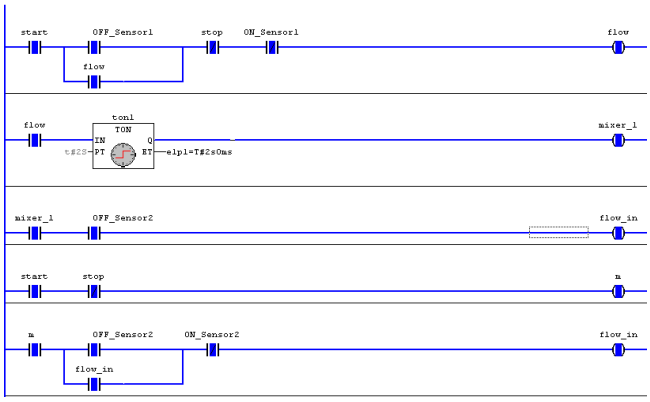
Start



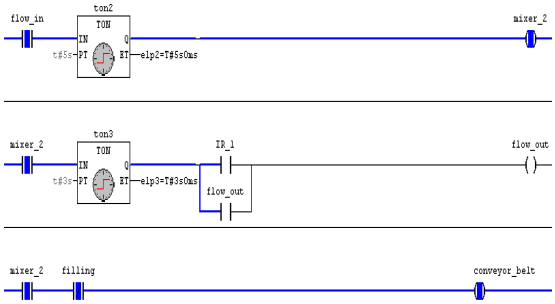
When OFF_Sensor1 of container1 is high, liquid flow into container1 and after 2s mixer_1 become on.



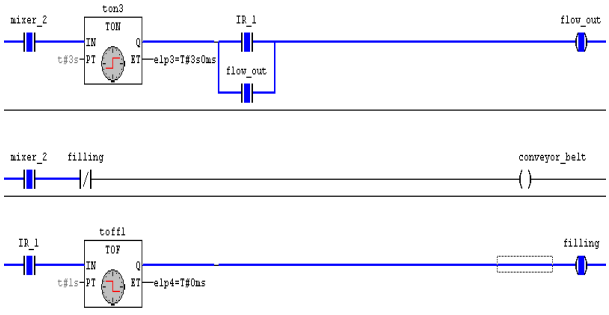
When OFF_Sensor2 of container2 is high, flow_in starts to container2.



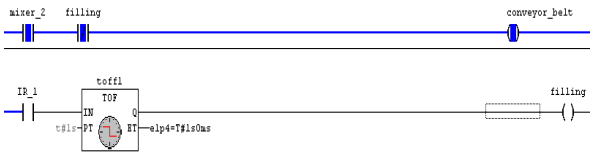
With delay of 5s mixing in container2 starts.



When IR_1 is high, conveyor stops and flow_out starts, which results in filling of bottles.



After 1s, filling stops and conveyor starts again.



When IR_2 is on, pressure is built in bottle.

When IR_3 is on, capping of bottle is done.

VII. CONCLUSION

Automation is greatest challenge in the present context of the world. Mixing of various liquid, filling and capping of bottles in the cold drinks manufacturing industry is challenge. In this paper, we proposed "PLC based automated flow controlled mixing, bottle filling and capping in cold drink manufacture industry" in order to make manufacturing process easy, less wastage, increased productivity and cost effective.

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