PLC based Design and Fabrication of a Carousel Automated Bottling System Controlled by Allen Bradley Software

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***Abstract* - In the processing and manufacturing industries there is great demand for industrial control system/ automation in order to streamline operations in terms of speed, reliability and product output. Automation plays an increasingly important key role in the world economy and in daily experience. The designed system, carousel automated bottling system includes the user defined volume selection at any desired level. The fabricated prototype processes are controlled by PLC using programming ladder logics developed in Allen Bradley software. The input and output module of the system plays important role in getting communication between PLC and prototype. Signaling conditions of I/O modules makes the system processes work accordingly with ladder logics developed. PLC is considered as the heart of any system in automation industries. Every result leads to the conclusion that the operation of PLC in is very inspiring. If the empty bottle to be filled is not present or detected, then the solenoid valve in that position is switched off, thereby avoiding wastage of the liquid.**

Keyword - Allen Bradley software, Automation, Bottling system, I/O Modules, Programmable Logical Controller (PLC)

I. INTRODUCTION

The field of automation and control system has made greater impact on the large variety of industries ranging from medium to large scale. The automation of industries plays a greater role in nations, where human resources are limited to overcome the pressure built continually for increasing production volumes. Limited resources lead to problems like higher costs, increase in lead time, poor quality, low production, and increased downtime. Automation has the greater capabilities of using the control systems, information technologies and monitoring to over reduce human intervention in the work.

The use of PLC software in an automated system to control the sensors and actuators has been greatly decreased the need for human sensory and mental abilities. One of the important applications of automation is in the food processing industries as such soft drink and other beverage industries, where a particular liquid has to be filled continuously. The levels of automation in the industry covers the complete production line, from receipt of goods, the production process, filling and packing, to shipment of goods. Many areas of manufacturing and processing are currently focusing on optimization and control technologies in order to improve performance and efficiency. In an increasingly competitive market, the industries are showing a clear need and strong desire to improve in the field of beverages [4].

II. PROBLEM DEFINITION

The paper put forth a technique to revolve problems in the existing bottling system. In linear conveyor system whereby all related processes on bottles are done at same conveyor causes bottleneck condition and overlapping of processes. In this paper DC motor is used with rotary index in carousel unit and relative speed is controlled by adjusting variable input loads. DC motor is easily operated by PLC ladder logics and timer block functions in PLC making it flexible to operate at multi modular application. But as in micro programming logics the system gets complicated for increase of each module interaction with the system within. Solenoid valve is used to fill the fluid to incoming bottles in the system. Solenoid valves are used as multi-volume level filling which can be easily done by PLC logic time delay techniques. There by overcoming the setting time and can be also be used for mixed-batch wise production system.

III. PLC

Programmable logic controller is a digital computer used for automation of industrial process, such as control of machinery on factory assembly lines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output unlike general purpose computers. Arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to controlled machine operations are typically stored in the battery backed or non –volatile memory [4].

The PLC performs the logic functions of relays, timers, counters and sequencers. The PLC scans its inputs and, depending on the program, switches on or off various combinations of outputs. The logic state of the output depends on the input conditions and so the term conditional logic is used [1].

IV. ALLEN BRADLEY SOFTWARE

Allen-Bradley is the brand-name of a line of Factory Automation Equipment manufactured by Rockwell Automation founded by Lynde Bradley and Dr. Stanton Allen in early 1900s. The company, with revenues of

approximately US$6.4 billion in 2013, manufactures programmable logic controllers (PLC), human-machine interfaces, sensors, safety components and systems, software, drives and drive systems, contactors, motor control centers, and systems made of these and similar products [9]. The prototype designed utilizes RSLogix 500 controller.

V. PROCESS DESCRIPTION

The 3D model for automated bottling system is designed using the CATIA software and is shown in Fig. 1. The approach to fabricated model is done with guidance of references below.

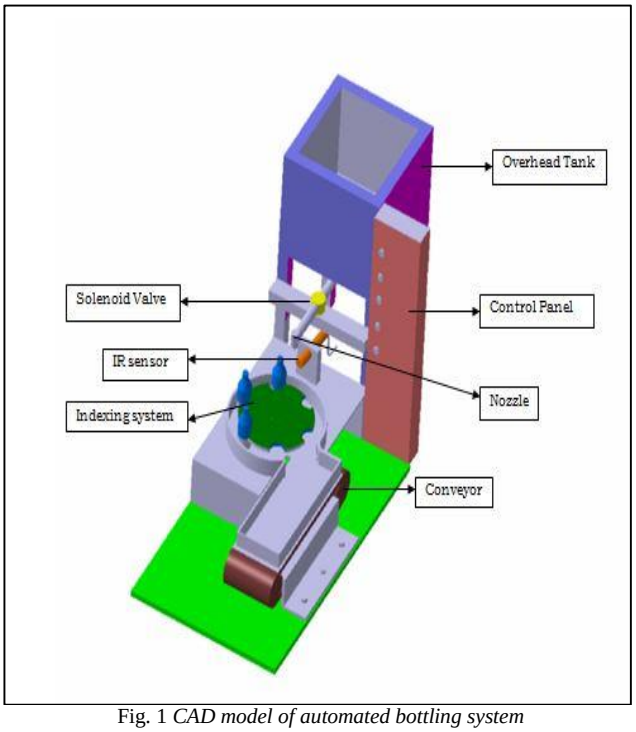
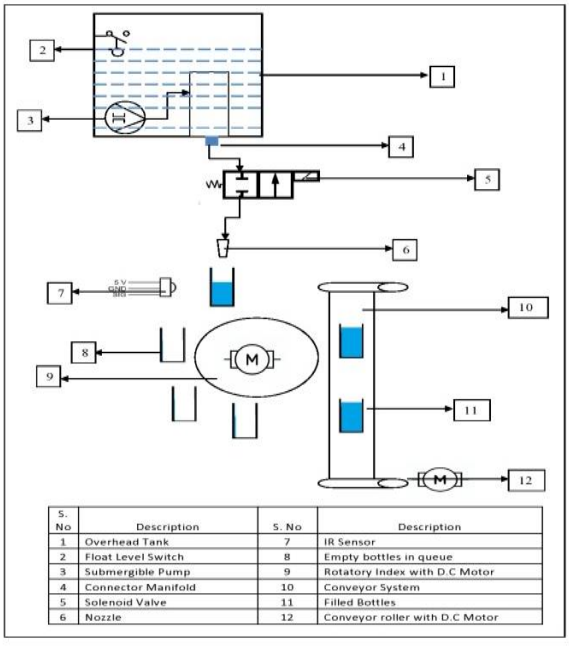


Fig. 1 *CAD model of automated bottling system*



S. No	Description	S. No	Description
1	Overhead Tank	7	IR Sensor
2	Float Level Switch	8	Empty bottles in queue
3	Submergible Pump	9	Rotatory Index with D.C Motor
4	Connector Manifold	10	Conveyor System
5	Solenoid Valve	11	Filled Bottles
6	Nozzle	12	Conveyor roller with D.C Motor

Fig. 2 *Schematic layout of system*

The schematic diagram describes the system interaction with various units. The linkage of each of the units is inevitable with its frame work. The schematics layout used in industries gives pictorial representation of each of processes in the system and its elements. It's a layman language for easy understanding of various processes taking place in the given system.

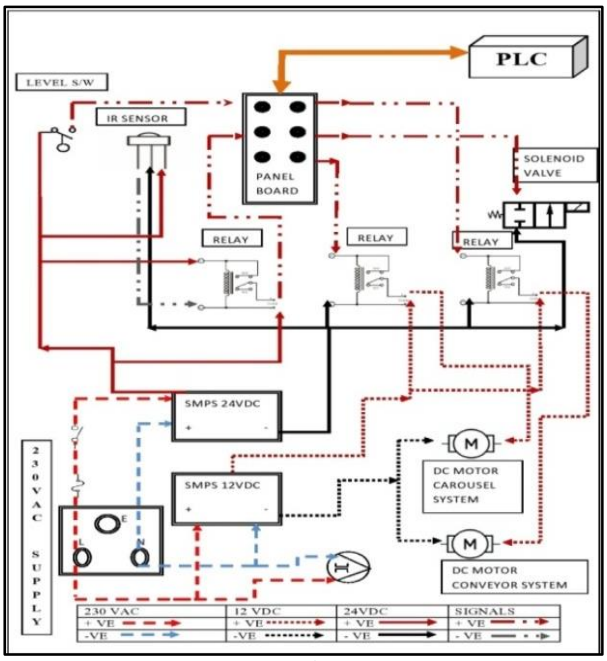


Fig. 3 *Circuit diagram of automated bottling system*

Circuit diagram of the automated bottling system is shown in Fig. 3. The acts like nervous system, which helps in connecting to the brain. Here the nervous system is referred to as the available wire frame connection to different units and its components control by PLC as it's brain, as per the given ladder logics. The whole system works on 24VDC supply. Since signals transmitted and received from PLC are in order of +VE 24 VDC. So, to make system fully functional, all system components are signaled as 24 VDC by usage of SMPS. In order to get 24 VDC relays are used making the whole system compactable to desired rated voltage.

5.1 Automated bottling system units

5.1.1 *Overhead tank*

5.1.2 *Carousel unit*

5.1.3 *Filling unit*

5.1.4 *Conveyor unit*

5.1.5 *Control panel*

5.1.1 Overhead tank

- Leak proof Tank
- Level sensor
- Constant height gauge
- Submergible pump

Overhead tank designed is of 10 liter capacity leak proof tank. Comprises of level sensor at particular desired point to activate the system at minimum liquid level and also acts as an indicator. The signal from the level sensor controls the filling action in the system. The use of submerge pump in the tank is to draws liquid from tank to constant head gauge, in order maintain constant pressure of liquid at any given time in the tank at all levels.

5.1.2 Carousel unit

- Rotating disc
- DC motor

The carousel unit consists of an indexed rotating disc attached to DC motor for rotation. The speed of the DC motor is adjustable with variable load current making easy for filling process.

5.1.3Filling unit

- IR sensor
- Solenoid valve
- Empty bottles

Filling unit consists of IR sensor and solenoid valve. This unit needs to be synchronized with the above units. Here the empty bottles arrive at from carousel unit and liquid to be filled from overhead tank. The IR sensor detects the empty bottles and solenoid valve fills liquid of relative quantity into empty bottles.

5.1.4 Conveyor unit

- Nylon rollers
- Leather belt
- Load cell

The conveyor unit consists of nylon rollers with leather belt about 3 inches width size. To revolve this conveyor unit a DC motor is used. Conveyor unit collects the filled bottles from the filling unit to do remaining further process in bottling plant.

5.1.5 Control panel

- Inputs
- Outputs
- LED lights
- Probes

Control panel to which all the system components are interfaced with each other to get desired output results. The probes are used for interconnect all the input or output modules to PLC. The LED lights present on the panel board gives the indication to programmer as for the activation of pulsating signal given to the I/O module by PLC programming and logics.

5.2 Input modules

Sensors: Includes the level sensors/switch and IR sensor; output signal from these sensors are given as an input to the PLC. Level switch is used to detect the minimum liquid present in the overhead tank, and IR sensor is used to detect the incoming empty bottles to in line with filling station. These sensors output signals are the inputs to DC motor and the solenoid valve in next unit stations.

5.3 Output modules

DC motors: The rotor of the motor produces torque from the interaction between the magnetic field in the stator and rotor. The strength of the magnetic fields is proportional to the amount of current sent to the stator. The RPM is variable to current supply. Here in ABS DC motors are used in both carousel and conveyor system.

Solenoid valve: Solenoid Valves are used in the industry to control the flow of all sorts of fluids. A solenoid valve is an electromagnetic valve for use with liquid or gas controlled by running or stopping an electrical current through a solenoid, which is a coil of wire, thus changing the state of the valve to open or close.

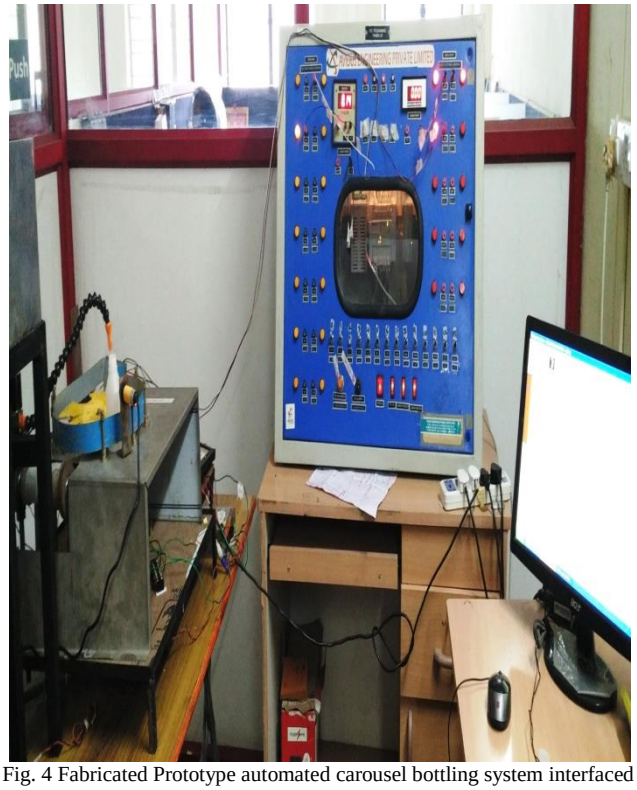


Fig. 4 Fabricated Prototype automated carousel bottling system interfaced with PLC

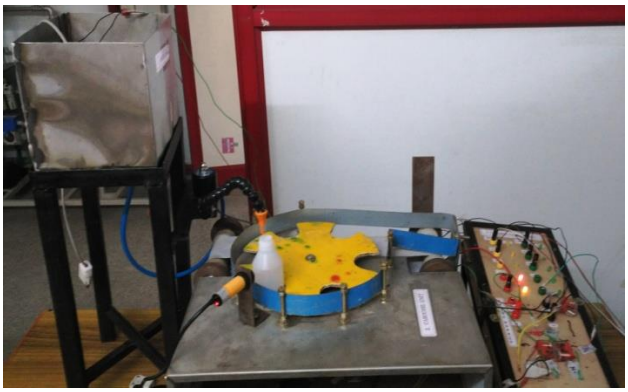


Fig. 5 Fabricated Prototype automated carousel bottling system

5.4 Operational description of system

Automated carousel bottle system is ready to operate only if the minimum of water level is observed in the overhead tank. The entire system is monitored by level sensor. After the water levels are achieved in overhead

tank, only then activation of carousel unit happens. The DC motor revolves the indexed disc guiding the empty bottles to filling station. When on detecting the empty bottles by IR sensor the carousel unit stops in-line to filling station nozzle. Here the solenoid valve is activated and controlled by the timer block function in the program to give time for filling the bottle with water. As per the time of delay changes the quantity of water filled. So the system is time depended. The volume to be filled can be changed as per the user by just altering the timer option in the program. After this the IR sensor is signaled low, so making the DC motor of carousel unit active for next coming empty bottle in queue. Thus making whole system closed loop and continuous operating by triggering one shot by bit operation in the ladder logic program.

VI. PLC LADDER LOGICS

PLC Ladder diagram

All the below programs in figures are written in Allen Bradley software with RS logix500. The different conditions of programming is shown in each status of logics acivation by the PLC in below figures are

- Program when the system is idle
- Program when the system is downloaded and active
- Program when the system is sensed high to level sensor
- Program when the system is sensed high to IR sensor
- Program when the system is sensed low to IR sensor and looping to continuous process

The activation of any logic can be seen, when the rung element are highlighted and show it's a healthy contact for the loop. Special instructions are used as such **TON** timer and **B3.0** for triggering one shot for continuous looping the program.

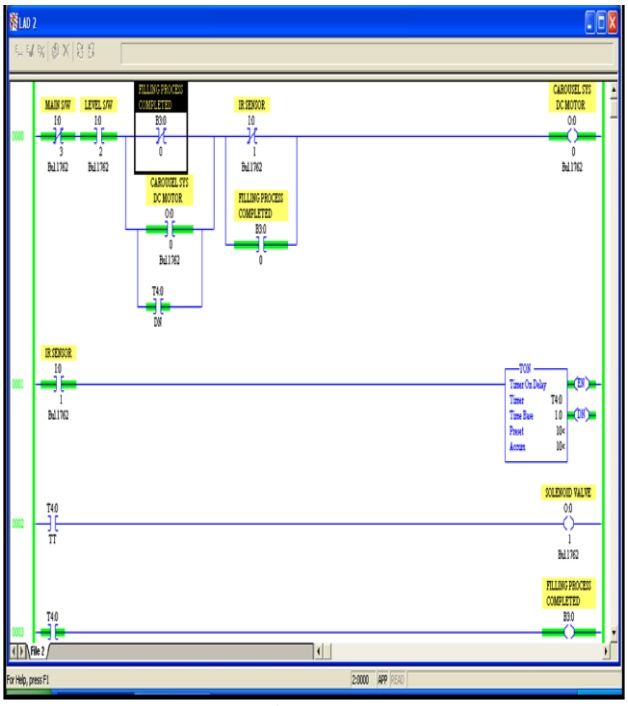


Fig. 5 *Ladder logic for automated bottling system*

VII. RESULTS AND DISCUSSIONS

In order to validate fabricated prototype, a series of 52 trial runs were conducted on the automated bottling system with the following parameters.

7.1 Fixed parameters of the system

- Shape and max volume capacity of the bottles i.e., cylinder and 80*ml*
- Material of the bottle is plastic
- Positioning of the filling station and the nozzle
- Rotary indexing size and number of slots are 6
- Operating speed

7.2 Desired parameters of the system

- Volume of water to be filled = 55 *ml*
- Net weight of the filled bottles = 60 *grams*

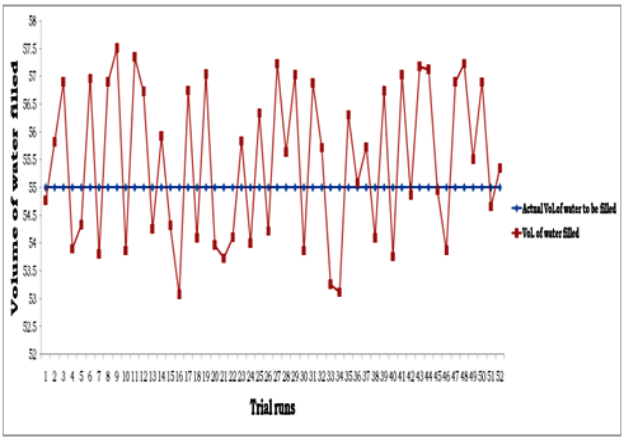


Fig. 6 *Graph representation of vol. of water filled in empty bottles*

Fig. 6 presents the graph of volume of water filled in the empty bottles during the 52 trial runs. The observed deviation to volume of water filled in empty bottles is between upper limit +2.5 *ml* to lower limit -1.13 *ml* from the desired value of 55 *ml.* with range of 3.63. The results were observed to fluctuating between +4.54% of upper limit to -2.05% of lower limit.

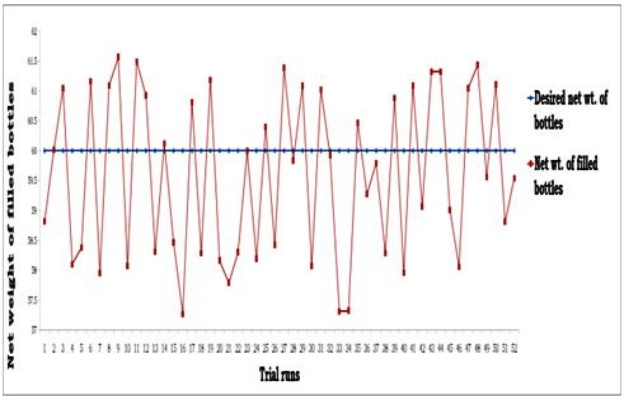


Fig. 7 *Graph representation of net weight of filled bottles*

Fig. 7 presents graph of the net weight of filled bottles with water during the 52 trial runs with respect to results obtained in previous graph and were draw downed from the load cell.

The observed deviation of net weight of filled bottles is between upper limit +1.56 *grams* to lower limit -2.01 *grams* from desired net value 60 grams with the range of 3.57. The results were observed to fluctuating between +2.06% of upper limit to -3.35% of lower limit.

VIII. CONCLUSIONS

An automated bottling system incorporates multiple processes as such; filling of empty bottles, capping, labelling, sorting into lots and packing. From the references taken represents view on linear conveyor system, but as of linear systems its difficult to perform multiple operations simultanously. Since each of operation in the bottling system is independent of time. Thus making it difficult for sychronization of all operational processes simultanously. Inorder overcome such a situation, an automated bottling system with carousel operating is design and fabricated. The automated bottlimg system proposed is independent of each of processes involved, there by preventing overlapping and bottleneck situations.

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